Science teachers designing context-based curriculum materials: developing context-based teaching competence

PROEFSCHRIFT

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Chapter 1

Introduction to the thesis

In 2007 a programme was set up in which high-school science teachers were provided with the opportunity to perform research into the different, context-based curriculum innovations of the science subjects. In the DUDOC-programme (acronym for Didactisch Universitair onderzoek van DOCenten naar vernieuwing van de bètavakken) teachers combine a PhD-research project (three days a week) with their teaching job (two days a week). I was one of the teachers accepted into this programme and have combined teaching practice with teaching research for four years. One of the opportunities for this programme is the input from research that could go back into teaching practice. The start for this input is the thesis lying before you. In the epilogue, I reflect on my experiences as a teacher-researcher and the implications this combination could have for the professional development and career opportunities for teachers.

Introduction to the thesis

In the high school where I teach physics the number of students choosing an economy-oriented profile is generally larger than the number of students choosing a science-oriented profile. Worldwide, Lyons (2006) has observed a decreasing number of students choosing a further education in science. To counter this trend, education in the science subjects has been moving toward a different pedagogic approach in many countries: a context-based approach (Bennett, Lubben, & Hogarth, 2007). In the UK, a higher interest among students to choose a future education in science is reported after twenty
years of context-based chemistry teaching (Bennett & Lubben, 2006). The learning results of context-based education are similar to those of traditional education (Bennett & Lubben, 2006). There is no clear research evidence that a context-based approach produces better learning results than other approaches (cf. Jochems, 2007).

In the Netherlands a curriculum innovation is taking place for the science subjects in the upper levels of secondary school, aiming at better learning results of the students and at more appreciation of the sciences (Boersma et al., 2007; Driessen & Meinema, 2003; Commissie Vernieuwing Natuurkunde Onderwijs HAVO/VWO [Innovation committee high school physics education], 2006; Commissie toekomst wiskundeonderwijs [Innovation committee high school mathematics education], 2006; Steering Committee Advanced Science, Mathematics and Technology, 2008). Despite the lack of evidence that a context-based approach leads to the desired better learning results, this approach is at the core of the Dutch innovation for biology, chemistry, physics and advanced science, mathematics and technology (ASMaT [NLT]).

The research presented here is not however, concerned with the effectiveness of the intended Dutch context-based innovation. It is concerned with changing the teaching practice towards context-based education. In anticipation of the context-based innovation, some science textbooks have started to use elements of the context-based approach. This can lead to the following example:

*My physics classroom, somewhere in februari 2009, upper level secondary education:*

\[
\begin{align*}
\text{Me:} & \text{ We start with the equation for pressure. Anyone?} \quad \text{Student1:} \\
& \quad p = \frac{F}{A} \quad \text{Me:} \text{ Well done. Next we look at the situation we are in. What is going on?} \quad \text{Student2:} \text{ There is pressure.} \quad \text{Me:} \text{ Yes, of what?} \\
& \quad \text{Student2:} \text{ From the air.} \quad \text{Me:} \text{ Yes?} \quad \text{Student3:} \text{ No, water pressure.} \quad \text{Me:} \text{ Okay. And why does water exert pressure?} \quad \text{Student4:} \text{ Because it has weight.} \quad \text{Me:} \text{ How much weight?} \quad \text{Student4:} \text{ Gravity.} \quad \text{Me:} \text{ Which is...?} \quad \text{Student1:} \text{ m times g.} \quad \text{Me:} \text{ Well done. Let’s put that into our equation.} \quad p = \frac{mg}{A}. \quad \text{So how do we calculate the mass of the water. Was it in the exercise?} \quad \text{Student2:} \text{ No, volume is.} \quad \text{Me:} \text{ So?} \\
& \quad \text{Student6:} \text{ Density maybe.} \quad \text{Me:} \text{ } \rho = \frac{m}{V}, \text{ do we remember?}
\end{align*}
\]
Class: (Murmurs no. A short diversion to the concept of density ensues). Me: Now we include the equation for density into this one. \( p = \rho \cdot V \cdot g \). What is \( A \)? Student2: Acceleration! Me: Really? Student7: No it is activity, you know, with \( \frac{1}{2} \) and so on. Me: Yeah, could have been, capital A, but does this exercise concern radioactivity? Class: No. Me: So? (silence) Area maybe? Class: Oh! Me: What is \( V_A \)? Student6: That’s something with cubic meter divided by meter squared, something with meter. Me: And what do we have with meter in this exercise? Student1: Fluid height! (we made it there: \( p = \rho \cdot h \cdot g \))

Reflecting on what happened here I came to the following:

*When I was new at teaching I would do the whole mathematical deduction on the chalkboard. Only explaining the step when necessary and the students copying the lines. Boring for the students, but reproducible for them. The new textbook introduces this same deduction in an exercise with a picture of a column of fluid and the standard equation for pressure. The deducted equation expected of the student is emphasised in the book. This is context-enriched education. But I have to do the deduction on the smartboard all the same, because the students do not see it. The added context does not explain why and how a column of fluid exerts pressure. The context is restricted and unclear. The teacher’s problem with this new, context-enriched textbook. Students need to be immersed into a context for them to understand which elements are important. Not just a nice picture and a deduction question . . .*

Had I been a book-dependent teacher, I would have only helped the students to work out the equation and moved on. To me however, this kind of context in a textbook question underlines the need to professionalise teachers towards the context-based innovation that is pending the decision of the Minister of Education and her staff.

There is a tendency in literature and the teaching community calling for the role and competency of teachers not to be limited to the classroom: they should also comprise (re-)design of educational materials and active support of the innovative educational practice in schools (SBL: Stichting beroeps-skwaliteit leraren en ander onderwijspersoneel [Association for the Professional Qualities of Teachers], 2004; Bennett & Lubben, 2006). Hence, teachers are not only required to professionalise towards context-based education
in teaching context-based materials, but also in (re-)designing context-based materials and education, and in supporting the innovation in their school. This thesis therefore concerns the professional development of these teachers.

Traditional professional development in workshops seems to fall short in supporting teachers’ professional development (Fullan, 1994) and is probably ineffective in acquiring context-based competency. In general, active participation in the innovation itself by teachers is claimed to be more effective (Cochran-Smith & Lytle, 1999; Fullan, 1994). In line with this, context-based educational materials are currently being designed in teams of science teachers led by science pedagogical professionals and under the authority of the four science innovation committees (ASMaT, biology, chemistry, and physics). This not only ensures that the new materials will fit classroom needs, but also engages the teachers in the innovative design process, and is likely to contribute to these teachers context-based competency. This thesis focuses on the question: how does the participation of teachers in context-based design teams (ASMaT, biology, chemistry, and physics) contribute to their professional development towards context-based teaching, and which factors concerning the design experience hinder or facilitate this development.

The insights gained from this research can be used to optimise teacher professional development sessions when the context-based innovation is being implemented nationwide. It complements other studies in this field like that of Stolk, Bulte, De Jong, and Pilot (2009a) and Coenders, Terlouw, and Dijkstra (2008) that focus on chemistry alone.

This introduction is followed by seven chapters. Each of the next six chapters has been submitted to, or is being published in (inter)national journals and a book. Each article or chapter reproduced here contains an introduction to the problem dealt with, the theory involved, research questions, results, and discussion and conclusions. The final chapter contains the general conclusion to this thesis. The content of each chapter following this introduction is outlined below.

Chapter two: instrument construction

In this chapter, the description of context-based education we use throughout the thesis is presented. This is done by reviewing literature on context-
based education. On this basis an instrument for measuring context-based teaching competency is developed, which is valid regardless of the science subject. Since learning outcomes will comprise various aspects (e.g. attitudes, knowledge, skills and competency), the instrument is based on methods such as classroom observations, semi-structured teacher interviews, analysis of designed material, and teacher-and-class questionnaires. The results from these data sources are triangulated to generate a comprehensive measurement of the teachers’ context-based teaching competency. The aim of this pilot study is to construct and validate a composite instrument for use in a multiple-case study (chapter five) and a professional development study (chapter seven). This chapter is accepted for publication in Learning Environments Research.

Chapter three and four: validating and benchmarking questionnaires

The use of questionnaires in our pilot study (chapter two) has the limitation that it is only tested among a small number of teachers and students. To increase the value of the questionnaires they need to be validated using a larger sample of teachers than available in the pilot study. To allow comparison of teachers on teaching competency in future studies (chapter five and seven) it would be useful to have national questionnaire data as a benchmark. Therefore the two different questionnaires from the composite instrument developed in chapter two are evaluated more extensively by using them in two nationwide studies (n=213 and n=1630). Chapter three was published in Tijdschrift voor didactiek der Bètavetenschappen; chapter four is accepted for publication in the book Teachers creating context-based learning environments in science.

Chapter five: multiple case-study on context-based competency

In chapter five, a multiple-case study using the validated instrument is described (n=33). The context-based teaching competency of science teachers (ASMaT, biology, chemistry, and physics) who designed materials for the context-based innovation under supervision of the different innovation committees is explored. Due to the planning of the PhD research this is a retrospective study since most teachers involved will have finished the project by the time the instrument is constructed and validated. The goal of the study is to uncover differences in context-based teaching competency
between teachers with and without context-based design experience, and between teachers of different science subjects. The instrument developed in chapter two is used as a tool to measure context-based competency. These teachers are also asked to attribute their development in context-based competency and report on their learning experiences during their time spend designing. Chapter five is accepted for publication in the *International Journal of Science Education*.

**Chapter six and seven: intervening in design of context-based materials to boost context-based competency**

In chapter six a framework is designed for a professional development programme that focusses on the design of context-based instructional material by science teachers as a means to acquire context-based teaching competency. The framework is based both on the results of the multiple-case study in chapter five that regard the learning process of teachers in design teams for curriculum material as well as literature on teacher professional development. Chapter six is submitted to an international journal.

Chapter seven describes a case-study of the learning of science teachers following the professional development programme designed in the previous chapter. The development of context-based competency in the participating teachers (n=6) is described and related to the design of the programme. Suggestions to optimise the programme are provided. This chapter is submitted to an international journal.

**Chapter eight: general conclusions and discussion**

In the final chapter the results from this research are discussed and general conclusions are drawn. Critical remarks on the results are made, followed by suggestions for future research. Some suggestions for the implementation of the Dutch context-based innovation are provided.
Chapter 2

Mapping context-based learning environments - the construction of an instrument


abstract

The current trend in science curricula is to adopt a context-based pedagogical approach to teaching. New study materials for this innovation are often designed by teachers working with university experts. In this article it is proposed that teachers need to acquire corresponding teaching competences to create a context-based learning environment. These competences comprise an adequate emphasis, context establishment, concept transfer, support of student active learning, (re-)design of context-based materials, and assistance in implementation of the innovation. The implementation of context-based education would benefit from an instrument that maps these competences. The construction and validation of such an instrument (mixed-methods approach) to measure the context-based learning environment is described in this paper. The composite instrument was tested in a pilot-study among teachers (n=8) and students (n=162) who use context-
based materials in their classrooms. The instrument’s reliability was established and correlating data sources in the composite instrument were identified. Various aspects of validity were addressed, and found supported by the data obtained. As expected, the instrument revealed that context-based teaching competence is more prominently visible in teachers with experience in designing context-based materials, confirming the instrument’s validity.

2.1 Introduction

Context-based education is the innovative approach to science education chosen in many countries to further the interest of students in science and to increase the coherence of the concepts studied in the national curricula (Bennett & Lubben, 2006; Gilbert, 2006; Pilot & Bulte, 2006b). A trend in this innovation is to encourage science teachers to collaborate with university experts in designing new study materials (Parchmann et al., 2006; Pilot & Bulte, 2006a). The collaborative process of developing and improving materials is expected to lead to a change in the cognition of the teachers (Coenders, 2010) and to permanent changes in their teaching practice (Mikelskis-Seifert, Bell, & Duit, 2007). Changes in cognition and teaching practice touch on the core competences of teachers mentioned in national governmental directives (cf. European Commission Directorate-General for Education and Culture, 2008). Such a change in teaching competence is essential for the innovation to succeed. The nature of the change in teaching competence required for context-based teaching is thus far undefined.

This study aims to describe both the teaching competences needed for creating a context-based learning environment and a composite instrument to map the context-based learning environment. This composite instrument includes learning environment questionnaires (cf. Taylor, Fraser, & Fisher, 1993), classroom observations, and semi-structured interviews. The context-based teaching competence can be derived from the learning environment teachers are able to create in their classrooms. Reliability and various aspects of validity (Trochim & Donnelly, 2006) of the composite instrument will be addressed. Dutch teachers who are working with the context-based materials for Advanced Science, Mathematics and Technology (ASMaT)\textsuperscript{1}, Biology, Chemistry and Physics are studied to consolidate the competences identified from the literature. Some teachers have worked

\textsuperscript{1}New Dutch science subject for year 10-12 where students discover social issues and the science involved. Concepts usually exceed the normal science curricula.
in design teams creating the material; others have not. Both groups of teachers should show the competences required to teach the innovative material since they use the material in class. However, it is expected that teachers who have experience in designing the innovative materials are better able to create a context-based learning environment and thus show more of the competences than their colleagues who have not had this experience. The finding of such a result would provide evidence for the instrument’s sensitivity. The proposed instrument is intended to map context-based learning environments, which is useful for research in the area of teacher professional development and studies into context-based teaching practices.

2.2 Context-based education

In this study the definition of a context-based learning environment follows that of the context-based approach by Bennett et al. (2007) in their review of research into the subject: “Context-based approaches are approaches adopted in science teaching where contexts and applications of science are used as the starting point for the development of scientific ideas. This contrasts with more traditional approaches that cover scientific ideas first, before looking at applications” (p. 348). To describe the nature of the contexts used in context-based education we follow Gilbert (2006). According to Gilbert (2006), contexts should have:

a setting within which mental encounters with focal events are situated; a behavioural environment of the encounters, the way that the task(s), related to the focal event, have been addressed, is used to frame the talk that then takes place; the use of specific language, as the talk associated with the focal event that takes place; a relationship to extra-situational background knowledge (Duranti & Goodwin, 1992, p. 6-8).

An important element of a context-based learning environment is active learning (Gilbert, 2006; Parchmann et al., 2006): the students are required to have a sense of ownership of the subject and are responsible for their own learning. The combination of self-directed learning and the use of contexts is consistent with a constructivist view of learning (Gilbert, 2006). As current research in science education points out: people construct their own meanings from their experiences, rather than acquiring knowledge from other sources (Bennett, 2003).
In addition to traditional characteristics of context-based learning environments, in this study the trend mentioned earlier for teachers to design (and teach) the innovative materials in close cooperation with pedagogical experts is added. Teachers designing and teaching innovative materials is expected to both create support from the teaching field for the innovation and more importantly to make the materials more applicable to the teaching practice (Duit, Mikelis-Seifert, & Wodzinski, 2007; Parchmann et al., 2006). This study is conducted in the Netherlands where a context-based innovation is taking place, involving teachers in designing curriculum materials for this innovation. Hence this specific addition was chosen.

The theory of context-based education is expected to proceed through a number of interpretative steps before it reaches the classroom practice (Goodlad, 1979). This study concerns the perceived, operational, and experiental curriculum levels, since it is aimed at teacher competences. The teacher perceives context-based education, interprets it and makes it operational in the classroom where it is experienced by students.

The focus in this study is on elements of a context-based learning environment from a teacher competency perspective and aims to develop an instrument to map the competences that can be used broadly for the four different science subjects.

2.2.1 Teacher competences for context-based teaching

As said, teacher competence forms the starting point for creating and investigating context-based classes.

In this study the definition of a competent teacher as formulated by L. Shulman and Shulman (2004) is used. They characterise an accomplished teacher as “a member of a professional community who is ready, willing, and able to teach and to learn from his or her teaching experience” (p. 259). Ready and willing imply abilities within the affective dimension and able implies abilities within the cognitive and behavioural dimension. This research is concerned with the affective, cognitive and behavioural aspects of teacher competence since it is known that in teacher (and student) learning many different psychological factors (e.g. emotional, cultural, motivational, cognitive) have to be taken into account (Shuell, 1996). A number of competences for context-based education are distinguished. These are well founded in literature and are recognised by experts (Plomp et al., 2008; De Putter-Smits, Taconis, Jochems, & Van Driel, 2009).
2.2.1.1 Context handling

The nature of the context-based approach to teaching requires teachers to be able to familiarise themselves with the context expressed in the material used in class. This differs from a traditional educational approach where the concepts are of foremost importance and are usually explained first before embarking on applications. The required teacher attitude towards contexts is phrased by Gilbert (2006) as: “[…], the teacher needs to bring together the socially accepted attributes of a context and the attributes of a context as far as these are recognised from the perspective of the students” (p. 965).

The context should cause a need for students to explore and learn concepts and to apply them to different situations. Teachers have to be able to establish scientific concepts through context-based education (Parchmann et al., 2006) and have to be aware of the need for concept transfer (to other contexts) (Van Oers, 1998). The teacher competence in handling contexts, establishing concepts and making the concepts transferable to other contexts is referred to in this paper as context handling.

2.2.1.2 Regulation

In a constructivist view of learning the following four learning dimensions are distinguished by Labudde (2008). The first dimension he distinguishes concerns the individual, i.e. knowledge is a construction of the individual learner. The second dimension concerns social interactions, i.e. the knowledge construction occurs in exchange with other people. The third dimension concerns the content. “If learning is an active process of constructing new knowledge based on existing knowledge [...] then the contents to be learned must be within the horizon of the learner” (Labudde, 2008, p 141). The fourth dimension concerns the teaching methods, i.e. the role of the teacher. The latter two dimensions are particularly important for context-based education, since these entail active learning of scientific concepts within a context. Labudde (2008) concludes that

the learning process of the individual and the co-construction of new knowledge can be to some extent be supported by ex-cathedra teaching and classroom discussions. But for promoting learning as an active process and for stimulating the co-construction of knowledge other teaching methods seem to be more suitable, e.g. students’ experiments and hands-on activities, learning cycles, project learning, or case studies (p. 141).
These so-called *other teaching methods* can be characterised as student active learning or student self-regulated learning. According to Vermunt and Verloop (1999) and Bybee (2002) such learning calls for specific teaching activities. The use of these teaching activities in evaluating context-based education has been shown to be effective by Vos, Taconis, Jochems, and Pilot (2010). Vermunt and Verloop (1999) identify activities under three levels of teacher control - strong, shared and loose. To achieve an intermediate or high degree of self-regulated learning a shared or loose control strategy by the teacher is called for (Bybee, 2002). Teaching activities to support a shared control strategy include: having students make connections with their own experiences, giving students personal responsibility for their learning, giving students freedom of choice in subject matter, objectives and activities, having students tackle problems together (Vermunt & Verloop, 1999). Teachers should be competent in handling these kinds of activity, i.e. to guide rather than control the learning process of the students. The teacher competence of regulating student learning is called the *regulation* competence in this study.

2.2.1.3 Emphasis

To facilitate the learning of concepts through contexts a different teaching emphasis from that usual in traditional science education is necessary (Gilbert, 2006). Emphasis has been defined thus by Roberts (1982):

> A curriculum emphasis in science education is a coherent set of messages to the student about science [...]. Such messages constitute objectives which go beyond learning the facts, principles, laws, and theories of the subject matter itself - objectives which provide answers to the student question: “Why am I learning this?” (p. 245).

Three emphases have been described for chemistry education by Van Driel, Bulte, and Verloop (2005, 2008) based on the work of Roberts (1982) and Van Berkel (2005) on the emphasis of the different science curricula. A similar classification of emphases to Van Driel et al. (2005) intended for *science education* in general has been proposed in a parallel study (De Putter-Smits, Taconis, Jochems, & Van Driel, 2011). These emphases are also used here:

- a fundamental science (FS) emphasis where theoretical notions are taught first because it is believed that such notions later on can provide a basis for understanding the natural world, and are needed for the students future education;
a knowledge development in science (KDS) emphasis where students should learn how knowledge in science is developed in socio-historical contexts, so that they learn to see science as a culturally determined system of knowledge, which is constantly developing:

a science, technology and society (STS) emphasis where students should learn to communicate and make decisions about social issues involving scientific aspects.

From the literature it is apparent that a KDS and/or STS emphasis is an important success factor for the context-based innovation (Driessen & Meinema, 2003; Gilbert, 2006). The use of emphasis to typify teachers’ intentions in the classroom when teaching context-based materials has been shown to be effective by Vos et al. (2010). Teaching from a KDS or STS emphasis is a teacher competence referred to in this study as emphasis.

2.2.1.4 Design

Seen from a constructivist perspective the context-based materials available are not automatically suited to every classroom or to the needs of all individual learners. Furthermore, the active role for the student embedded in the context-based curriculum material requires activities like experiments and puts a demand on the time tables. Not all schools may have the opportunity to meet these requirements and demands, creating the necessity for the teachers to redesign the material to the schools’ facilities. Another consequence of active learning is the sometimes unpredictable learning demands from the students, causing the teachers to redesign education on the spot. Learning issues that might confront students are not generally predictable, requiring teachers to change their lesson plan to the demands of the student. Teachers are therefore expected to (re-)‘design’ the context-based material to their needs. Hence, it may also be expected that the educational design of curriculum materials teacher competence is more demanded in context-based education than in traditional education.

2.2.1.5 School innovation

Finally, the context-based innovation cannot succeed if it is supported only by isolated teachers (Fullan, 1994). The teachers are to be seen as representatives of this innovative approach in their schools: explaining the ins and outs of context-based education to colleagues, providing support on context-based issues, and collaborating with teachers from other science
subjects to create coherence (cf. Boersma et al., 2007; Steering Committee Advanced Science, Mathematics and Technology, 2008). The teachers have to implement the context-based approach together with colleagues of their subject field and even possibly across science subjects to create coherence in the science curricula. In a study into the learning effects among teachers involved in developing ‘Chemie im Kontext’ (ChiK), an increased belief and wish to collaborate within schools is observed. These teachers are also likely to be involved in multifaceted collaborative relationships in their own schools (Gräsel, Fussangel, & Parchmann, 2006). The teacher competence involving collaboration is referred to in this study as school innovation.

A list of five teacher competences for context-based education was thus deducted from literature: context handling, regulation, emphasis, design, and school innovation. The teacher competences concerning context handling, emphasis and teaching regulation have also been used in the ‘physics in context’ (piko) studies (Mikelskis-Seifert et al., 2007). In the study described here, an attempt is made to develop a learning environment instrument to measure these components of teachers’ context-based competences. They are evaluated on three dimensions: affective, cognitive and behavioural. Reliability and validity (Trochim & Donnelly, 2006) are evaluated with a small sample of teachers.

2.2.2 The Dutch context-based innovation: teachers designing context-based education

The Dutch Ministry of Education, Culture and Science instituted committees for the high school subjects biology, chemistry, physics, and advanced science mathematics and technology (ASMaT). The assignment was to develop new science curricula that would better suit modern science, relieve the current overloaded curricula and possibly interest more students in choosing science in further studies (cf. Kuiper, Folmer, Ottevanger, & Bruning, 2009a). The science curricula in this innovation were meant for years 10 and 11 of senior general secondary education and for years 10-12 of pre-university education. The subject ASMaT differs from the other science subjects in that it is a new school subject for which, up to then, no curriculum or learning goal had been designed (Steering Committee Advanced Science, Mathematics and Technology, 2008).

The innovation committees were committed not to present a ‘list of concepts’ to the Ministry of Education, Culture and Science, but to provide
a tried and working curriculum from year 10 up to the national exams (cf Driessen & Meinema, 2003). To this end, they enlisted teachers to develop aspects of the curriculum, i.e. curriculum modules, textbooks, workbooks, worksheets for experiments and so on. Each of the novel science curricula has been tested in test-schools for three years. The nationwide implementation is now pending the Minister’s approval.

All Dutch innovation committees decided to use a form of context-based education (Boersma, Eijkelhof, Van Koten, Siersma, & Van Weert, 2006). However each committee differed in the specification of the elements of context-based education, the extent to which this approach should be visible in the curriculum materials, and how design teams for curriculum materials should be set-up.

The work in design teams, such as the Dutch innovation committees instigated, is an example of circumstances that generally lead to successful professional development of teachers in small groups (of teachers) (Deketelaere & Kelchtermans, 1996). For context-based education, changes on the cognitive and behavioural dimension in teaching practices of teachers designing their own curriculum materials were found (Mikelskiis-Seifert et al., 2007). The context-based design experience of the teachers that designed curriculum materials and used theses materials in class is thus considered an opportunity for teacher professional development, leading to the assumption that teachers with design experience have more context-based teacher competences than teachers without this experience. No instruments have yet been constructed to measure context-based teaching competency. Such an instrument would enable research in the area of context-based teaching competence and the development of such competence.

2.2.3 Research questions

The first research question was:

Can a composite instrument able to measure the identified context-based teacher competences of science teachers teaching context-based oriented science classes in a reliable and valid manner be developed?

Assuming that the answer to the first research question will be positive, the second research question is:
Is there a positive correlation between context-based teacher competence and the use of context-based materials in class and / or experience in designing context-based teaching materials?

The research questions are answered by designing and evaluating a composite instrument in a pilot study into the context-based learning environment of teachers who use the innovative context-based material in their classes. These teachers vary in their years of teaching experience, in whether or not they had context-based design experience, and in whether or not they use their own context-based materials in class. This allows an evaluation of the sensitivity of the instrument.

2.3 Method

2.3.1 Instrument design

Competence measurement can be described as: “Detailed research into the actions of a teacher in the classroom practice; an empirical analysis of professional work” (Roelofs, Nijveldt, & Beijaard, 2008, p. 323). Mapping the learning environment a teacher is able to create therefore is also mapping a part of the competence of this teacher on the aspect concerned.

The mapping of a learning environment calls for a mixed-methods approach, to draw upon the strengths and minimise the weaknesses associated with different methods of research (Johnson & Onwuegbuzie, 2004, p 17). An instrument that consisted of quantitative and qualitative components was composed to map each of the five identified teaching competences on each of the three dimensions. An overview of the composite instrument\(^1\) with the competences and dimensions it covers, and the number of variables that map each competence is provided in Table 2.1.

The instrument was a composite of two international standard questionnaires, two semi-structured interviews, classroom observations (and subsequent interview) and an analysis of curriculum materials. These six components within the instrument provided a total of 65 variables that are described below. Each variable was used as an indicator for a teacher competence in the 15-cell competence matrix as depicted in Table 2.1.

\(^1\)An overview of the questions in the interviews and questionnaires can be requested from the corresponding author
Qualitative data were given a score by two researchers independently. Six researchers (including first and second author) in the field of context-based education and teacher competence were involved in the research, both in establishing codebooks for scoring qualitative data as in the scoring of these data. Examples of such scoring of qualitative data are provided per component in subsequent sections. The corresponding variables from each of the instrument-components were combined to arrive at 15 competence scores. Each cell of the matrix contained at least three variables to enable triangulation (Johnson & Onwuegbuzie, 2004) of the different scores. Inter-source correlations were checked to ensure the combination of the data sources. If a low inter-source correlation was found true differences with respect to that competence between the sources was further investigated and checked for relevance, rather than considered a measurement error. For instance, the student and teacher perception on teacher-student interaction may differ and may be meaningful (Den Brok, Bergen, & Brekelmans, 2006). At least two data-sources per variable were kept.

To support the described triangulation of data, a *competence description* was formulated per participating teacher. All teachers were then asked to comment on this description of their teaching competence.

The design, reliability, and validity of the components in the composite instrument are detailed in the subsequent sections.

### 2.3.1.1 Teacher and class questionnaire: WCQ

The first component of the instrument was a questionnaire based on appropriate scales from the ‘what is happening in this classroom’ (WIHIC), the ‘constructivist learning environment survey’ (CLES) and the ‘questionnaire on instructional behaviour’ (QIB) questionnaires, abbreviated to WCQ (questionnaire). The questionnaires mentioned measure more and other learning environment elements than those that have been identified in this paper as indicative for a context-based learning environment. Therefore, only the scales from these questionnaires linked to one of the five context-based competences were selected.

The WIHIC questionnaire originally developed by Fraser, Fisher, and McRobbie (1996) measures school students’ perceptions of their classroom environment, including among others student involvement, cooperation, teacher support, and equity. The *investigation* scale measures the extent to which there is emphasis on skills and inquiry and their use in problem solving and investigation in a classroom (Den Brok, Fisher, Rickards, & Bull, 2006).
Table 2.1: Detailed overview of the composite instrument: the competences in terms of the dimensions.

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Source</th>
<th>Design</th>
<th>Emphasis</th>
<th>Regulation</th>
<th>Context-handling</th>
<th>School innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Affective</td>
<td>WCQ questionnaire</td>
<td>CLES personal relevance scale; teacher perspective</td>
<td>CLES shared control and student negotiation scales; QIB strong, shared and loose control scales; teacher perspective</td>
<td>WIHIC investigation scale; teacher perspective</td>
<td>Teacher scores on this questionnaire</td>
<td>Teacher scores on this questionnaire</td>
</tr>
<tr>
<td>Emphasis</td>
<td>Teacher scores on this questionnaire</td>
<td>Teacher scores on this questionnaire</td>
<td>Teacher scores on this questionnaire</td>
<td>Teacher scores on this questionnaire</td>
<td>Teacher scores on this questionnaire</td>
<td>Teacher scores on this questionnaire</td>
</tr>
<tr>
<td>Context-based education interview questions</td>
<td>Teacher scores on this questionnaire</td>
<td>Teacher scores on this questionnaire</td>
<td>Teacher scores on this questionnaire</td>
<td>Teacher scores on this questionnaire</td>
<td>Teacher scores on this questionnaire</td>
<td>Teacher scores on this questionnaire</td>
</tr>
<tr>
<td>Regulation</td>
<td>Teacher scores on this questionnaire</td>
<td>Teacher scores on this questionnaire</td>
<td>Teacher scores on this questionnaire</td>
<td>Teacher scores on this questionnaire</td>
<td>Teacher scores on this questionnaire</td>
<td>Teacher scores on this questionnaire</td>
</tr>
<tr>
<td>Design</td>
<td>Teacher scores on this questionnaire</td>
<td>Teacher scores on this questionnaire</td>
<td>Teacher scores on this questionnaire</td>
<td>Teacher scores on this questionnaire</td>
<td>Teacher scores on this questionnaire</td>
<td>Teacher scores on this questionnaire</td>
</tr>
</tbody>
</table>

No. of variables: 8

* Used with teachers with design experience only.

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Mapping context-based learning environments
Table 2.1: Detailed overview of the composite instrument -continued.

<table>
<thead>
<tr>
<th>Cognitive Source</th>
<th>Context handling</th>
<th>Regulation</th>
<th>Emphasis</th>
<th>Design</th>
<th>School innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Context-based education interview questions</td>
<td>What are the definitions and details of context-based education, familiarity with concept transfer, does the context-based teaching experience correspond to the teachers' definition (teacher perspective), indication of change in cognition on context-based education in storyline-graph</td>
<td>Differences in how students approach teacher, how teacher approaches students and other differences from traditional education; cognitive dimension views</td>
<td>After describing three different approaches to teaching a science concept corresponding to each of the three emphases, what is the teacher's preference, why, would it have been different before you started teaching context-based education; cognitive dimension views</td>
<td>How did the teacher interpret the context-based study module, what kind of preparatory work the teacher decided was necessary before teaching the study module, comparing the amount of work with other standard teaching methods; cognitive dimension views</td>
<td>Questions on cooperation with colleagues inside and outside school; cognitive dimension views</td>
</tr>
<tr>
<td>Classroom observations and subsequent interview questions</td>
<td>Cognitive dimension views that are visible in class or expressed during the discussion on how the class went afterwards of specific elements of context-based education such as preparatory work, presenting the context, treating cooperation</td>
<td>Indication of student and teacher control in the classroom varying from loose to strong control in a graph</td>
<td>After describing three different approaches to teaching a science concept corresponding to each of the three emphases, what is the teacher's preference, why, would it have been different before you started designing context-based curriculum materials; cognitive dimension views</td>
<td>Storyline type questions on change in knowledge and skills of designing curriculum materials; cognitive dimension views</td>
<td>Inquiring after cooperation with people inside and outside school; cognitive dimension views</td>
</tr>
</tbody>
</table>

* Design and context-based skills interview questions

| No. of variables | 3 | 3 | 3 | 3 | 3 |

* Used with teachers with design experience only
Mapping context-based learning environments

Table 2.1: Detailed overview of the composite instrument - continued.

<table>
<thead>
<tr>
<th>Source</th>
<th>Context Handling</th>
<th>Regulation</th>
<th>Emphasis</th>
<th>Design</th>
<th>School Innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td>WCQ questionnaire</td>
<td>CLES personal relevance scale; student perspective</td>
<td>CLES shared control and student negotiation scales; QIB strong, shared and loose control scales; student perspective</td>
<td>WIHIC investigation scale; student perspective</td>
<td>Behavioural dimension views of the core context-based innovation of the core concept, learning of the concept, teacher perspective, behaviour and cognition.</td>
<td>Classroom observations and subsequent interview questions</td>
</tr>
<tr>
<td>Classroom observation</td>
<td>student perspective</td>
<td>Behavioural dimension views that are visible in classes or expressed during the discussion on how the class went onwards of specific design and implementation.</td>
<td>Behavioural dimension views that are visible in classes or expressed during the discussion on how the class went onwards of specific design and implementation.</td>
<td>Behavioural dimension views that are visible in classes or expressed during the discussion on how the class went onwards of specific design and implementation.</td>
<td>Behavioural dimension views that are visible in classes or expressed during the discussion on how the class went onwards of specific design and implementation.</td>
</tr>
<tr>
<td>No. of variables</td>
<td>5</td>
<td>9</td>
<td>5</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

* Used with teachers with design experience only
Typical values of Cronbach’s alpha for this scale range from 0.85 to 0.88 (Den Brok et al., 2006; Dorman, 2003). This scale relates to the KDS emphasis defined in the theory section of this paper and was used as a variable measuring the emphasis competence. The CLES constructed by Taylor, Fraser, and Fisher (1997) measures the development of constructivist approaches to teaching school science and mathematics. Scales include personal relevance, uncertainty, critical voice, shared control, and student negotiation. In this study the scales and descriptions from Johnson and McClure (2004) were used. To measure the context handling competence the personal relevance scale was used. For the emphasis competence the uncertainty scale was used. Shared control and student negotiation were used to measure the regulation competence. Typical values of Cronbach’s alpha for these scales range from 0.76 to 0.91 (Johnson & McClure, 2004; Lee & Fraser, 2000; Taylor et al., 1997).

The Questionnaire on Instructional Behaviour (QIB) (Lamberigts & Bergen, 2000) was originally developed to measure teachers’ instructional behaviour. Scales included clarity, classroom management and teacher control. From the QIB the scales for strong, shared and loose teacher control were selected, corresponding to the context-based teacher competence regulation. Typical values of Cronbach’s alpha for these scales lie between 0.64 and 0.86 when used in Dutch classrooms (Den Brok et al., 2006).

All scales selected from the different questionnaires use a five-point Likert scale ranging from ‘I completely disagree’ to ‘I agree completely’. In Table 2.2 the selected scales, a sample item and the competence that it is expected to map is provided, as well as a summary of the resulting WCQ questionnaire.

The questionnaires were translated into Dutch. Two versions of the WCQ questionnaire were used, one to map teachers’ perceptions and one to map students’ perceptions. The teacher questionnaire mapped the teacher’s self-perceptions on their class at the affective dimension. The student questionnaire mapped the students’ perceptions on the way the class is taught; the behavioural dimension. The student questionnaires were completed by the class anonymously to obtain unbiased answers. Each scale corresponded to either an instrument variable on the affective dimension (teacher questionnaire) or the behavioural dimension (student questionnaire), providing 18 variables for the composite instrument.
### Table 2.2: Scale name and sample item of the WCQ questionnaire including the competence they map

<table>
<thead>
<tr>
<th>Questionnaire</th>
<th>Scale name</th>
<th>No. of items</th>
<th>Sample item</th>
<th>Competence</th>
</tr>
</thead>
<tbody>
<tr>
<td>WIHIC</td>
<td>Investigation</td>
<td>8</td>
<td>I carry out investigations to test my ideas</td>
<td>Emphasis</td>
</tr>
<tr>
<td>CLES</td>
<td>Personal relevance</td>
<td>4</td>
<td>New learning relates to experiences or questions about the world inside and outside of school</td>
<td>Context handling</td>
</tr>
<tr>
<td></td>
<td>Uncertainty</td>
<td>4</td>
<td>Students learn that science is influenced by people’s cultural values and opinions</td>
<td>Emphasis</td>
</tr>
<tr>
<td></td>
<td>Shared control</td>
<td>4</td>
<td>Students help me to decide which activities work best for them</td>
<td>Regulation</td>
</tr>
<tr>
<td></td>
<td>Student negotiation</td>
<td>4</td>
<td>Students explain their ideas to other students</td>
<td>Regulation</td>
</tr>
<tr>
<td>QIB</td>
<td>Loose control</td>
<td>3</td>
<td>S/he lets us determine our own pace in working on tasks</td>
<td>Regulation</td>
</tr>
<tr>
<td></td>
<td>Shared control</td>
<td>6</td>
<td>S/he stimulates us to help each other when working on a task</td>
<td>Regulation</td>
</tr>
<tr>
<td></td>
<td>Strong control</td>
<td>3</td>
<td>S/he tells us how to study for a test</td>
<td>Regulation</td>
</tr>
</tbody>
</table>

#### 2.3.1.2 Emphasis teacher questionnaire

The second component of the instrument was a rephrased version of a questionnaire used by Van Driel et al. (2008) to measure the preferred curriculum emphasis of chemistry teachers in secondary science education. The questionnaire originally contained 45 statements to which answers were obtained using a five-point Likert scale. The 45 items were divided into three sub-
scales, each corresponding with a different teaching emphasis. The scores per emphasis (FS, KDS, and STS) were obtained by adding the scores of the corresponding items. Typical alpha correlation values for the original questionnaire ranged from 0.71 to 0.82. The questionnaire mapped the opinion of teachers (affective dimension). In a parallel study the questions were rephrased to represent science education in general and science-subject-specific questions were rephrased such that they also represent biology and physics (De Putter-Smits et al., 2011). For ASMaT teachers the assumption was made that the general science education questions represented the teachers’ view of ASMaT. The scales for ASMaT therefore consisted of fewer items. The rephrased questionnaire was validated in a study among 213 science teachers with alpha correlation values ranging from 0.73 to 0.90 (De Putter-Smits et al., 2011).

In the present study the scores on the three emphasis scales were combined into one variable by adding the scores for STS and KDS emphasis and subtracting the score for FS emphasis, in accordance with the preferred emphasis competence outlined in the theory section. The mutual correlation between KDS and STS was 0.45 ($N = 213; p < 0.00$, De Putter-Smits et al. (2011)), indicating that these concepts partly overlapped (convergent validity). Hence the combined variable represented the common core of context-based teaching emphasis.

### 2.3.1.3 Interview on context-based education

The teachers’ affective and cognitive skills and their classroom behaviour regarding context-based education were measured using a semi-structured interview. The questions were based on the five components of context-based teacher competence discussed in the literature section. Face validity of the interview model and the code book for categorising the answers (Ryan & Bernard, 2000) was confirmed by a panel of researchers (first and second author and one independent researcher). The answers were analysed and entered as variable scores.

For instance, the question ‘Could you explain what context-based education is, your personal opinion?’ and ‘What do you feel is the difference between context-based science education and traditional education?’ required the teacher to respond at the cognitive dimension and possibly behavioural dimension on the teacher competence context handling and regulation. The answers were compared to the context-based teacher competence definitions derived from literature (see theory section). The teachers were then com-
pared to each other using fractional ranking (cf. Field, 2005) per variable and scored one to total number of teachers in the study (in this study eight), the highest number representing the most proficient teacher in this variable. Teachers with no score on a variable were not included in the fractional ranking of that variable.

An example of such ranking is: teacher A tells the researcher that “context-based education requires strict teacher instruction and a constant monitoring of progress, including good old-fashioned deductions of concepts ’cause the context-based material do otherwise not result in students learning the concepts”. Teacher B does not see a difference in regulating student learning between standard science education and context-based education. “It is maybe, just that the students seem to have different questions”. Teacher C tells the researcher that he is now “guiding the students towards learning the concepts, rather than just telling them. It is more work, ’cause I have to coach each group of students separately and differently, but it is worthwhile”. Ranking these teachers would result in teacher A scoring 1, since she expresses views contrary to the intentions of context-based education, teacher B scoring 2 since she sees only a small difference that she cannot position and teacher C scoring 3 since he is describing behaviour expected in context-based education.

2.3.1.4 Classroom observation and interview

Classroom observations and subsequent interviews were used to establish context-based proficiencies on the three dimensions. For each teacher, up to three classes were video-taped and the voice of the teacher was recorded separately. The subject of the classes observed were: the start of a new study module where the context (focal event) would be most visible; a class which would be an example of student-active learning; a class where concepts would be most prominent e.g. the last lesson prior to a test. The lesson was then analysed on the five teacher competences on each of the three dimensions using codebooks (Ryan & Bernard, 2000). Face validity of the codebook was confirmed by the panel of researchers (first and second author and one independent researcher).

Typical context-based teaching behaviour was counted (tallied) on the behavioural dimension. For instance, the teachers embarks on an explanation of the context and in class recuperates three times what he has said about it would lead to a count of 4 on the behavioural dimension,
context-handling competence. When teachers expressed a train of thought when engaging in for instance a teaching activity, this was categorised and counted on the cognitive dimension. For instance, the teacher described what activities are expected of the students and how they are responsible for the learning of their group. She continues to coach two of the groups along these lines. On the cognitive dimension the total would be 1 on the regulation competence and on the behavioural dimension the competence would count 2. When teachers expressed an opinion on one of the competences this was categorised and counted on the affective dimension.

After the observed class the teachers were interviewed on how they though or felt the context-based class went. All remarks in their context-based teaching were checked against the definitions of context-based education from the theory section of this article. Answers indicating context-based teaching competence were also counted.

The scores were then calculated by dividing the counted occurrences of the context-based behaviour and context-based after-class discussion remarks by the number of minutes of class observed. This part of the instrument also provided 15 variables per teacher.

2.3.1.5 Analysis of designed material

Curriculum material teachers designed themselves was analysed for evidence of the five context-based teacher competences identified from literature. The scores were added as five variables on the behavioural dimension since the teachers concretise their ideas and knowledge and put them into action in the curriculum material.

The material was analysed on the use of contexts to introduce concepts, concept transfer, on the use of a KDS and/or STS emphasis, on the stimulating of active learning and on cooperation with other science domains. For this a codebook was used. Face validity of the codebook was confirmed by the panel of researchers.

An example of context-based style material would be a remark encouraging students to look-up unfamiliar scientific concepts they encountered in the context before proceeding (student regulated learning). The material was scored on a three point scale from ‘opposite from context-based education’ to ‘in accordance with context-based education’. The example given, would thus obtain the score 3 on the regulation competence. Teachers who had not made any material for their classes were not given a score on these variables.
2.3.1.6 Interview on design and context-based skills

The teachers with experience in designing materials for the current science innovation were interviewed in depth on their experience. Using a interview combined with a storyline technique (Taconis, van der Plas, & van der Sanden, 2004) changes in the different context-based competence components of the teachers were established. The semi-structured interview started with general questions on teaching experience and general questions on what context-based education entails. Next, the teachers were asked whether their attitude, knowledge, skills and classroom behaviour towards context-based education had changed due to their design experience, using a storyline technique (cf. Beijaard, van Driel, & Verloop, 1999). To ensure all context-based design related learning was discussed the teachers were asked to name subjects related to their design experience that were not covered in the interview questions.

The questions covered all competence cells, providing 15 variables for this part of the instrument. Face validity of the interview model and the code book for categorising the answers was confirmed by the panel of researchers. Similar to the interview on context-based education skills, the answers per competence were checked against the definitions of context-based education derived from literature and the teachers were ranked (fractional) from one to no. of teachers, the highest number representing the most proficient teacher. For instance: teacher A replied that designing context-based education was only different in that the applications of scientific concepts were now treated first, rather than the concepts. Otherwise for him the structure of the lessons remained the same. Teacher B replied that designing context-based curriculum materials was very time-consuming since he had to come up with a suitable context that would cover all the concepts he intended to be part of the curriculum module. Comparing these two teachers, teacher A was ranked 1 and teacher B was ranked 2.

2.3.2 Cases

Eight teachers using the innovative material in their classrooms in the south-east region of the Netherlands were selected randomly by inviting teachers by email through the innovation network. This request was answered positively by three teachers in the domain Advanced Science, Mathematics and Technology (ASMaT), one biology teacher, three chemistry teachers and one physics teacher. Four of these teachers had experience in designing context-based material. Two of the four teachers taught using the material
they designed themselves. For seven of the eight teachers it was their first year teaching the innovative material. For one teacher it was his second year.

The unequal number of cases per science subject and unequal distribution per year-level are both due to limited response to the request. One class of students per teacher (with year-level relevant to the innovation) was selected for observation. The limited number of cases is due to the limited number of teachers (around 60) that use the innovative material in class at the time of this research. On the other hand, a number of eight is quite customary for mixed-methods approaches and would allow a first evaluation of reliability and validity.

2.3.3 Analysis

Two researchers independently analysed all data using the codebooks to obtain a score in the different cells. An inter-rater kappa (Cohen, 1988) was calculated to ensure the instrument measured reliably. The scores on all variable items were recalculated into standard scores (z-scores) based on the item mean and standard deviation before they were used in the analyses to correct for influences from the different scales of measurement. The (standardised) scores obtained on the variables per component per cell were correlated to establish reliability and convergent validity (Trochim & Donnelly, 2006) of the instrument. Correlating and non-correlating variables were thus identified and non-correlating variables were excluded in future use of the instrument, unless the low correlation found corresponded to a theoretically expected difference in perception on that issue considered relevant by prior research.

To be able to answer the second research question and to validate the instrument fully, competence scores for each competence cell per teacher were calculated. After identifying and removing the non-correlating variables in Table 2.1, the remaining variables per competence cell were averaged, first within each actor’s perception (student, teacher, researcher) then all perceptions were averaged. This was done to give equal weight to each party’s opinion. The accumulation of opinions was based on research that shows that consensus in opinion on someone increases with an increasing number of observers (Kenny, 2004). Missing data were treated as empty cells.

An example of a calculation of a score per teacher, in the cell context handling within the affective dimension: the WCQ scale personal rele-
vance gave an average that was then standardised to 0.34, meaning that the teacher scores (relatively) above average and towards context-based teaching; 1 being exactly according to context-based education intentions. Then the z-scores for the answers to interview on context-based education questions were averaged with the scores on answers to questions from the design and context-based skills interview namely −0.21, meaning that the teacher scored (relatively) below average and contrary to context-based education intentions. Next these two averages where again averaged, to obtain the final score per teacher, 0.065, meaning that the teacher shows (almost) no competence on the context handling context-based teaching competence on the affective dimension.

A context-based competence table of z-scores was thus created per teacher. The scores were then put into words, for instance the emphasis competence score of −0.75 within the affective dimension was described as “you prefer to teach the concepts first and explain what they are used for later”, and a score of 0.87 on the regulation competence within the behavioural dimension was described as: “Your have a preference for a shared regulation teaching strategy in your classes, which is both observed in your classes as indicated by the student questionnaires.” All of the 15 scores were thus translated back to words and sent to the teachers to be able to compare the teachers’ self perceptions with this competence description. The teachers were asked to give both feedback on each competence described and a percentage of agreement on their competence description. This feedback from the teachers provides an indication of the instrument’s reliability.

The competence (z-) scores per cell per teacher calculated were used to establish differences between teachers with and teachers without relevant design experience by correlating scores and ‘design experience’ using Spearman’s rho for ranked variables. As mentioned in a previous section we expect teachers with design experience to show more context-based competences. The competence scores per cell were also correlated with ‘using self-designed context-based materials’, since teachers who used the material they designed themselves in their classes are more aware of the intention of the material than the other teachers. To ensure these were the only influencing factors ‘teaching experience’ was also correlated with the scores per cell. If design experience, use of self-designed material and more teaching experience correlated to higher context-based competence scores, this added to the instrument’s validity (concurrent).
A quantitative data analysis was performed, even though the number of cases was small \((n=8)\) to test the instrument constructed on its reliability and validity. The result as such thus only has an indicative meaning for the ultimate goal of mapping teachers context-based learning environment and corresponding teaching competences.

### 2.4 Results

The first main question was whether the identified context-based competence components can be measured in a reliable and valid manner.

#### 2.4.1 Reliability

The composite instrument was found to give reliable results. The WCQ student questionnaire was returned by 88 percent of the students. Incomplete questionnaires were excluded from the analysis. The alpha coefficient for the scales used in the student WCQ questionnaire ranged from 0.74 to 0.87 \((n=162)\), which is comparable to previously published results for the scales used in this questionnaire (Den Brok et al., 2006; Dorman, 2003; Taylor et al., 1997)

Per teacher one or more (up to three) classes were observed. The interpretation of the observed classes by using the video and audio footage has been done simultaneously and independently by a second researcher. Cohens’ kappa was calculated to be 0.65. Next, the general impression of the class observed was discussed and agreed upon and context-based competence scores were compared until full agreement was obtained. A ‘design and context-based interview’ was conducted with four of the eight teachers. The different interviews were analysed and scored by two researchers independently, reaching an inter-rater agreement of 0.72. Any curriculum materials that the teachers designed for their classes were analysed and scored independently by two researchers, reaching complete agreement.

The resulting teacher competence description was compiled by two researchers independently which occurred also in complete agreement. Seven teachers returned their context-based competence description with comments on the descriptions of the different competences. The overall agreement (teacher self-perceived and researchers’ perception) with the presented
competence description was 85 percent. All five context-based teacher competences were recognised by the participants. Four participants were of the opinion that active learning can occur even when the teacher has a strong control regulative approach to teaching.

### 2.4.2 Convergent validity

For each cell of the instrument matrix the scores of the different variables were correlated. Variables correlating above 0.35, indicating a substantial overlap of the variables, were selected for use in further study. Since the number of cases was small, no significance of the correlations found can be given. In Table 2.3, the range of correlation values (‘Pearson’s r’) and the number of correlating variables per cell are given. In some cases only one of the instrument components supplied data, so no correlations could be given.

Table 2.3: Number of remaining variables in the composite instrument and the range (some cells contained more than two variables; see Table 2.1) of the correlations between them.

<table>
<thead>
<tr>
<th>Context handling</th>
<th>Regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>no. of r</td>
</tr>
<tr>
<td>Affective</td>
<td>3 0.54-0.82</td>
</tr>
<tr>
<td>Cognitive</td>
<td>3 0.37-0.99</td>
</tr>
<tr>
<td>Behaviour</td>
<td>4 0.46-0.97</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Emphasis</th>
<th>Design</th>
<th>School innov.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>no. of r</td>
<td></td>
</tr>
<tr>
<td></td>
<td>variables</td>
<td></td>
</tr>
<tr>
<td>Affective</td>
<td>4 0.47-0.75</td>
<td>-</td>
</tr>
<tr>
<td>Cognitive</td>
<td>3 0.41-0.55</td>
<td>3 0.48-0.87</td>
</tr>
<tr>
<td>Behaviour</td>
<td>1 -</td>
<td>-</td>
</tr>
</tbody>
</table>

The WCQ scale *shared control* (CLES) correlated significantly (0.59-0.64) with the *strong control* scale from the QIB. The mean student score on the *shared control* (CLES) was rather low compared to the mean on the *shared control* (QIB) scale (2.72, SD= 0.28 vs. 3.22, SD=0.31). The WCQ
scale *strong control* (QIB) seemed to be linked to the other two QIB scales in that it did not measure the opposite construct (positive correlations). This effect was not apparent when correlating scores with other data such as interviews and classroom observations, where a negative correlation is obtained\(^2\). It can therefore be argued that these scales should therefore be removed from the composite instrument.

The instrument appeared to be valid for the competences context handling and regulation and partly for the competences emphasis and design, indicated by rather high correlations (convergent validity) between the variables.

For the competences emphasis, design, and school innovation no correlations could be calculated due to a lack of data (input from the teachers; hardly any material designed, no cooperation with other teachers taking place etc.).

Using the positively correlating variables only (32 of the 65), a Cronbach’s alpha of 0.84 was obtained for the composite context-based competence instrument.

The means and standard deviations of the (standardised) scores of the participants were calculated and are shown in Table 2.4. The results show that the scores of our participants as a group approach zero, indicative of a correct use of the z-score procedure. The standard deviations are large however, indicating that the instrument was able to discriminate between the different teachers and thus that the individual competence scores are meaningful and indicative of context-based teaching competence.

### 2.4.3 Sensitivity evaluated through teacher characteristics

The second research question dealt with the differences in context-based competence between teachers with and without design experience, teachers with more years of teaching experience, and teachers using self-designed materials in class. The individual competence scores per teacher for correlating variables (from Table 2.3) from the composite instrument were used, to obtain nine *scales* of context-based competences (the non-italicised cells in Table 2.4). The nine scales included three for the context handling competence, two for the emphasis competence, three for the regulation competence.

\(^2\)In this study the focus was on the overlap between the various perceptions on each of the competences as long as this overlap is found to be large enough, rather than on the possible meaning of contrasting opinions on a particular competence.
Table 2.4: Mean scores and standard deviation of the eight participants

<table>
<thead>
<tr>
<th></th>
<th>Context handling</th>
<th>Regulation</th>
<th>Emphasis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Affective</td>
<td>−0.04</td>
<td>0.79</td>
<td>0.18</td>
</tr>
<tr>
<td>Cognitive</td>
<td>−0.13</td>
<td>0.65</td>
<td>−0.04</td>
</tr>
<tr>
<td>Behaviour</td>
<td>−0.06</td>
<td>0.55</td>
<td>0.06</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Design</th>
<th>School innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Affective</td>
<td>−0.23*</td>
<td>0.96*</td>
</tr>
<tr>
<td>Cognitive</td>
<td>−0.03</td>
<td>0.85</td>
</tr>
<tr>
<td>Behaviour</td>
<td>0.17*</td>
<td>0.84*</td>
</tr>
</tbody>
</table>

Only one variable provides the * z-scores; not used in further analyses.

tence and one for the design competence. Inter-correlations were between 0.37 and 0.99 indicating good convergent validity (Cohen, 1992) of the nine scales.

The scores per competence per teacher were correlated with design experience, years of teaching experience and use of self-designed material versus given material using Spearman’s rho for ranked variables. The correlations are shown in Table 2.5.

Table 2.5 yields some strong indications of the instrument’s sensitivity; the average $r$ equalling 0.30.

First, the correlations found indicate that for the eight teachers studied design experience resulted in a higher context-based teacher competence for context handling and emphasis on the cognitive dimension ($r = 0.87$ and $r = 0.77$ respectively).

Second, more teaching experience correlated to a higher context-based teacher competence for context handling on the affective dimension and design on the cognitive dimension ($r = 0.88$ and $r = 0.95$ respectively).

Third, using self-designed material correlated to a higher context-based teacher competence for context handling on the cognitive dimension ($r = 0.76$). In terms of effect size this correlation found is large (Cohen, 1992).

Finally, when correlating the total context-based competence score for the eight teachers with design experience, years of teaching experience and
use of own material versus given material, years of teaching experience correlated significantly \((r=0.74)\) on the affective dimension and design experience on the cognitive dimension \((r=0.87)\).

Given the theoretically expected influences used in the correlations on the context-based teaching competences it could be concluded that the instrument’s validity is supported for the constructs of context handling, emphasis, and design and was thus valid to measure context-based teacher competence.
2.5 Conclusions and implications

The composite instrument to map the context-based learning environment created by the teacher developed in this pilot study has been shown to be reliable. The inter-rater results, the Cronbach’s alpha’s and the agreement of the teachers’ self-perception with the researchers’ constructed competence descriptions were high, indicating the instrument measured reliably (convergent reliability). The various components of the WCQ questionnaire were of undisputed translational validity (Trochim & Donnelly, 2006). The composite instrument was validated by identifying the correlating components. The high teacher agreement on their competence descriptions adds to the concurrent validity. Relational validity was addressed by looking at expected influences of teaching and design experience on context-based teaching competence. Teachers using their self-designed context-based material showed a higher competence score on the cognitive dimension. Hence discriminant validity appeared to be supported. This was not so for the regulation competence. No conclusions could be drawn for the discriminant validity on this competence. The significant correlations indicated the criterion validity of the instrument was sound. Correlating components could be used in further research. Considering the sample size, in further use of the instrument reliability and validity should be addressed further to ensure the instrument will be able to discriminate between different learning environments. Also, some improvements are advisable, detailed below.

The WCQ scale shared control (CLES) was not unambiguous, judging from the high correlation with the QIB strong control scale and the difference in means with the QIB shared control scale. The QIB strong control scale correlated negatively with other data sources on strong control and has been described by others as measuring the whole concept of teacher control (Den Brok, Bergen, Stahl, & Brekelmans, 2004). Since the composite instrument is extensive it could be suggested that these two scales will be omitted from the WCQ questionnaire in future.

The first and second author found it difficult to discriminate between affective and cognitive competence elements. Discrimination between these two dimensions in teacher research is known to be a challenge (Fenstermacher, 1994) and often the two dimensions are combined (Meirink, 2007). To increase the practicality of the instrument when using it in future research the affective and cognitive dimensions could be collapsed, resulting in two dimensions in which the context-based competences are measured. One
dimension depicting teachers’ opinions and knowledge on context-based education and one depicting the behavioural / classroom performance of context-based education (from a competence perspective). A similar analysis structure has been used by Meirink (2007) in analysing individual teacher learning when working in groups.

Using the data from the research presented here, the reliability for context handling, regulation and emphasis within such a combined affective / cognitive dimension is sufficient (Cronbach’s alpha = 0.95, 0.71, and 0.64 respectively). The collapsing of the two dimensions also makes the analysis of the data shorter and less complex, since there would then only be 10 scores to calculate.

On the behavioural dimension positive correlations were found for the variables of the context handling competence. The reliability coefficients for the emphasis and regulation scale were 0.80 and 0.93 respectively.

Apart from the proposed changes, it could be concluded that the instrument was reliable and valid for measuring the context-based learning environment using both quantitative and qualitative data. The composite learning environment instrument appeared to be able to measure the five context-based teaching competences on the affective/cognitive dimension and three of the competences (context handling, regulation and emphasis) on the behavioural dimension. For design only measurement on the affective/cognitive dimension was possible.

The design competence could be measured reliably on the cognitive dimension, but could not be measured on the affective dimension or behavioural dimension, probably due to the limited number of participants. However, the proposed collapsing of the affective and cognitive dimension resolves the measurement problem of the affective dimension. More research on the measuring of the design competence on the behavioural dimension is needed since design skills are required when embarking on context-based education (see theory section).

The school innovation competence gave results only for one variable on the cognitive dimension (teacher’s self-perception), making it impossible to obtain correlations. Further data could be obtained not only by studying the teacher point of view of this competence, but also by inquiring of the teacher’s direct colleagues on the school innovation competence. Also more observations by the researcher in the school where the teacher works would
reveal more on this competence. Triangulation of the data would then be possible and practicality, reliability and validity of data thus obtained can then be studied.

The competences teachers need to create a context-based science learning environment as presented in the theory section of this paper, have all been found in the context-based learning environments studied here, judging from the teachers’ standard deviations (Table 2.4). The competences school innovation and design however, were far less prominent than the other three (missing data in Tables 2.3 and 2.4). This can be explained since it is only recently that such teaching competencies have been called for (eg. SBL: Stichting beroepskwaliteit leraren en ander onderwijspersoneel [Association for the Professional Qualities of Teachers], 2004).

Four teachers in this study were of the opinion that active learning can occur even when the teacher has a strong control regulative approach to teaching. This contrasts strongly with research by Vermunt and Verloop (1999) and Bybee (2002) who state that for active learning to be successful a shared or loose control strategy is necessary. It demonstrates the necessity for teacher professional development in order for the context-based innovation to succeed.

The composite instrument resulting from this study was shown to be able to measure context-based competence of science teachers. Despite that the sample size (n=8) is small, positive indications were found of the instruments’ validity. In future research, the instrument could be evaluated further with a larger sample size in studying teachers’ context-based competences in the Netherlands and other countries.

So far, context-based science education has been evaluated on the learning outcomes of students and the motivation of students (Bennett et al., 2007), but not on the actual change in teaching in the classroom. One use of this instrument is to map the learning of teachers who start teaching context-based education. Comparisons could be made using the instrument between the context-based learning environments in the various countries where context-based science education has been implemented (e.g. Germany, UK, and the Netherlands). It can also be used to establish the differences in context-based learning environments and teacher competences per science subject.
Chapter 3

Science teachers’ preferred curriculum emphases and implications for curriculum innovations


abstract

The curriculum innovation committees for high school biology, chemistry and physics in the Netherlands suggest the use of the concept-in-context approach to teaching science (Michels, Boersma, & Gommers, 2009), although the exact interpretation of this approach varies according to subject. The teachers using the innovative curriculum and materials are expected to adopt a teaching emphasis corresponding to this approach when teaching the new curriculum. This research uncovers the current teaching emphasis preferences among teachers of these three science subjects as well as possible emphasis preferences per science subject. Also the possible influences of teaching experience and material design experience on emphasis
preference are considered. Using a previously validated questionnaire we approached biology, chemistry and physics teachers throughout the Netherlands (n=213). The results show that within the subjects, biology teachers prefer a ‘science technology and society’ emphasis and physics teachers prefer a ‘knowledge development in science’ emphasis. Between the subjects biology teachers were found to have a significantly stronger preference for a ‘science, technology and society’ emphasis than their colleagues from chemistry and physics. No other influences on teaching emphasis were found. Considering the emphasis preferences found among the different subjects it is expected that the innovation of the biology curriculum will meet with the least friction with teachers’ emphasis.

3.1 Introduction

In the Netherlands, governmentally instituted committees have been working on a new curriculum for high school biology, chemistry and physics since 2003. The curricula are commonly based on the context-based approach (Michels et al., 2009; Boersma et al., 2006). The committees for each of the three subjects adopted approaches that differed in detail in both the vision documents and in the pedagogical concept evident in the try-out instructional material made to test the new curriculum (Boersma et al., 2007; Driessen & Meinema, 2003; Commissie Vernieuwing Natuurkunde Onderwijs HAVO/VWO [Innovation committee high school physics education], 2006). Teachers as implementers are a key factor for an innovation to succeed (Fullan, 1994). The teachers’ beliefs on how a subject they teach should be taught are a leading factor in the integration of an innovation in the classroom (Pajares, 1992). Although the innovation committees ensure acceptance of the new curriculum by the teaching field through involving teachers and others in the innovation, there is as yet no research whether or not the innovation is supported by the teachers it concerns. A concept that can be used to study the beliefs of teachers on the pedagogy of science subjects in comparison with the proposed context-based approach is ‘curriculum emphasis’ (Van Driel et al., 2008). This paper deals with the question: “What is the current belief of biology, chemistry and physics teachers concerning the teaching of a science curriculum using the concept of ‘curriculum emphasis’ and does this belief hinder or facilitate the introduction of the proposed curriculum innovation?”
3.2 Context-based approach and Emphasis

Worldwide, many interpretations of the context-based approach are used. In a review of all these approaches Bennett et al. (2007) define the context-based approach as:

"Context-based approaches are approaches adopted in science teaching where contexts and applications of science are used as the starting point for the development of scientific ideas. This contrasts with more traditional approaches that cover scientific ideas first, before looking at applications (p. 348)."

The innovation committees have jointly chosen the context-based method though their approaches differ in detail. A common principle on which the committees agree is that students should be able to use the scientific concepts within authentic contexts. The definition of these contexts differ between the science subjects, but they have agreed that contexts are of an authentic or professional nature and become meaningful to the student by the learning activities they perform (Boersma et al., 2006).

The context-based approach is often proposed to counter the shortcomings in traditional science education. In a review by Gilbert (2006) the shortcomings of traditional chemistry education are summed up:

1. Overload [...], curricula have become over-loaded with content [...]. The consequences of high content loads have been that curricula are too often aggregations of isolated facts detached from their scientific origin [...].

2. Isolated Facts. These curricula are being taught without students knowing how they should form connections within and between the aggregations of isolated facts. [...] This can only lead to low engagement in classes and the forgetting of material thereafter.

3. Lack of transfer. Students can solve problems presented to them in ways that closely mirror the ways in which they were taught. They signal fail to solve problems using the same concepts when presented in different ways. [...].

4. Lack of relevance. When chemistry ceases to be a compulsory subject in the curriculum (usually at the minimum school-leaving age), the great majority of students does not
Science Teachers’ Preferred Curriculum Emphases

elect to continue to study it. Moreover, many of those that do elect to continue to study the subject experience a lack of relevance in it and seem to view it in an instrumental way, [...].

5. Inadequate emphasis. The traditional emphases of the chemistry curriculum have been the provision of a ‘solid foundation’ […], ‘correct explanation’ […], and ‘scientific skill development’ […] as the basis for more advanced study of chemistry. However, this set of emphases is, on its own, increasingly seen as an inadequate basis for such study (p. 958).

In the Netherlands this conclusion is supported by the so-called ‘Eenhoornnotitie’ (A. M. W. Bulte et al., 2000) that advocates the development of a coherent chemistry curriculum designed by teachers and educational experts together. In this report the remedy for the shortcomings listed above is suggested as a tailored version of the context-based approach, similar to the German (Mikelskis-Seifert et al., 2007; Parchmann et al., 2006) and British (Bennett & Lubben, 2006) model. Analogously to the German model (Parchmann et al., 2006) the Dutch committees have chosen to enlist the aid of teachers to produce context-based instructional materials to be able to test the new curricula. The concept curricula for the three science subjects were used in experiment in (between seven and twelve) different schools per subject and level, starting september 2007 (Michels et al., 2009).

The (insufficient) curriculum emphasis mentioned by Gilbert is based on the definitions of curriculum emphases by Roberts (1982):

A curriculum emphasis in science education is a coherent set of messages to the student about science […]. Such messages constitute objectives which go beyond learning the facts, principles, laws, and theories of the subject matter itself - objectives which provide answers to the student question: “Why am I learning this?” (p. 245).

From this general definition he identified seven different curriculum emphases in instructional materials for various science subjects. These emphases are depicted in Table 3.1. Each ‘emphasis’ can be viewed from the perspectives of each of the four actors in education: scientists, students, teachers and society. In our study we limit ourselves to the teachers’ perspective since it is teachers that will develop the context-based innovation
Table 3.1: The seven curriculum emphases by Roberts (1982, p 247-248)

<table>
<thead>
<tr>
<th>Emphasis</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid foundation</td>
<td>Stresses science as cumulative knowledge</td>
</tr>
<tr>
<td>Structure of science</td>
<td>How science functions as a discipline</td>
</tr>
<tr>
<td>Science / Technology decisions</td>
<td>The role scientific knowledge plays in decisions which are socially relevant</td>
</tr>
<tr>
<td>Scientific skill development</td>
<td>The 'science as process' approach</td>
</tr>
<tr>
<td>Correct explanations</td>
<td>Science as reliable, valid knowledge</td>
</tr>
<tr>
<td>Personal explanations</td>
<td>Understanding one’s own way of explaining events in terms of personal and cultural (including scientific) influences</td>
</tr>
<tr>
<td>Everyday applications</td>
<td>Using science to understand both technology and everyday occurrence</td>
</tr>
</tbody>
</table>

and put it into practice. Roberts considers that the intention of the writer of the instructional material can be misinterpreted by the teacher who uses it, analogous to the difference between the intended and interpreted curriculum recognised by Goodlad (1979). Another possibility is that the writer’s intention lies outside the teacher’s personal frame of reference causing the teacher to overlook the core intention of the material. Furthermore a conflict of loyalties can occur when a teacher has a different emphasis preference than the one incorporated in the instructional material (Roberts, 1982, 1988). According to Orpwood and Roberts (1978) it is to be expected that the different ‘emphases’ that are used in instructional material are translated into different teaching strategies. These teaching strategies do not affect the form of the lesson itself, but the political and social background of the teachers that colours their approach to the curriculum (Roberts & Orpwood, 1982). In our research we are interested in the emphasis preferences of the teacher. We define these as: the preferences that teachers have on the coherent set of messages to the student about science; such messages constitute objectives which go beyond learning the facts, principles, laws, and theories of the subject matter itself.

The curriculum emphases defined by Roberts have been previously applied in many different forms and contractions in for instance a study into the educational policies in Canada, in designing and analysing instructional materials, and in teacher education (Orpwood, 1985; Roberts & Orpwood, 1995; Van Berkel, 2005). Inspired by the previous contraction by Van Berkel
Van Driel et al. (2005, 2008) have shown in a study into the beliefs of chemistry teachers in the Netherlands that Roberts’ seven curriculum emphases can be contracted to three emphases. The three emphasis Van Driel et al. defined have been used by Vos et al. (2010) in a study into the intended emphasis of a designer of chemistry instructional material, the emphasis recognised by the teacher using this material, and the actual emphasis the teacher showed using the material in class. In our research we use a similar contraction to Van Driel et al. and Vos et al. from seven to three emphases. We do however focus on ‘science’ in accordance with Robert’s original research. The contraction we use and our definition of the three curriculum emphases are elaborated on below and depicted in Table 3.2.

Table 3.2: Three curriculum emphases for science education

<table>
<thead>
<tr>
<th>Name</th>
<th>Emphases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fundamental Science (FS)</td>
<td>Solid foundation, Correct explanations</td>
</tr>
<tr>
<td>Knowledge development in science (KDS)</td>
<td>Scientific skill development, Structure of science, Personal explanations</td>
</tr>
<tr>
<td>Science, technology and society (STS)</td>
<td>Science / Technology decisions, Everyday Applications</td>
</tr>
</tbody>
</table>

The first of the curriculum emphases is fundamental science (FS) where the scientific theories are taught first, because it is believed that this knowledge forms a fundamental base to understand the world, and that this knowledge is necessary for the students’ further education. The second curriculum emphasis is knowledge development in science (KDS) where students learn how scientific knowledge is developed in socio-historic contexts. In this way they learn that science is a culturally determined knowledge system that evolves continuously. The third curriculum emphasis is science technology and society (STS) where students are expected to be able to communicate about and make decisions on subjects from society that have scientific aspects.

According to the joint statement on the context-based approach published by the Dutch innovation committees, contexts have on the one hand a pedagogic purpose and on the other hand they can be the connector to the social experience domain where science and mathematics are involved. It is
however important to select contexts and relevant scientific concepts that are closely related. Also the contexts must be adapted to education in such a way students can acquire the intended scientific concepts (Boersma et al., 2006). This social experience domain where science is involved requires a pedagogic view more represented by the latter two curriculum emphases (KDS and STS) than the first (FS). This in accordance with the change in curriculum emphasis Gilbert suggests in his article describing context-based education (Gilbert, 2006). From a first evaluation of the new curricula (Kuiper, Folmer, Ottevanger, & Bruning, 2009b, 2009c; Kuiper et al., 2009a) it can be concluded that the innovative instructional materials made for biology and chemistry can be classified as context-based education as described by Bennett et al. (2007). We expect therefore that teachers with a KDS or STS curriculum emphasis preference to be more capable of applying the innovative curriculum and instructional materials in their classes than teachers with an FS emphasis (Pajares, 1992).

In our previous research on the emphasis preference of teachers who use the innovative instructional material we found that teachers who had cooperated in the design of the material had a strong KDS / STS emphasis preference (De Putter-Smits, Taconis, & Jochems, in pressb). An increasing teaching experience did not seem to be related to an emphasis preference. Experienced teachers seemed to have found a balance between the three emphases, each relevant at different times. In this research the emphasis preference of biology, chemistry and physics teachers in the Netherlands is studied.

Our research wil answer the following questions:

1. Is it possible to measure the emphasis preference for the teaching of the science subjects biology, chemistry and physics using an analogous method to the one used for chemistry teachers only?

2. What is the current emphasis preference for teaching the science subjects biology, chemistry and physics in the Netherlands?

3. What are the differences in emphasis preference for teaching the science subjects between biology, chemistry and physics teachers in the upper levels of secondary education in the Netherlands?

4. What are the influences of age, teaching experience and design experience of a teacher on the emphasis preference for teaching science subjects?
Using the results of our research, implications for the context-based curriculum innovation can be formulated.

3.3 Method

3.3.1 Instrument

Up to now the study published by Van Driel et al. (2008) has been the only one applicable to the Dutch situation where a qualitatively satisfactory instrument was designed to measure emphasis preferences of teachers. Beside the adequate reliability of the items in their scales the constructs measured by the instrument have been validated. In our research we created a parallel version of the instrument to be able to use it for all three science subjects. The original questionnaire contained a number of background questions and 46 statements on chemistry education to which a response was asked on a five-point Likert scale ranging from ‘I agree completely’ to ‘I disagree completely’. The 46 statements can be classified into three scales, one for each emphasis. In all the statements the phrase ‘chemistry education’ has been changed to ‘science education’. For chemistry-specific statements alternatives were formulated per subject, which were then put before a panel of experts (experienced teachers in secondary education) to ensure the statements were of the same importance and represented the same conceptual complexity they had in the original subject area.

For instance knowledge of chemical equilibria is important to me because students can use it to understand a wide range of chemical phenomena. has been rephrased for physics into: knowledge of energy conservation is important to me because students can use it to understand a wide range of physics phenomena. and for biology into: knowledge of the survival urge of organisms is important to me because students can use it to understand a wide range of biological phenomena.

The list of statements thus obtained has been tested for reliability and validity among 67 teachers of high school biology, chemistry and physics (non-random sample from the network available to the researchers) that were asked to fill in the questionnaire and to comment on the statements where necessary. This method confirms the face validity of the instrument, making it credible that the questionnaire is valid for the subjects biology, chemistry and physics. By calculating the internal correlations of the instru-
ment’s scales the reliability of the rephrased statements can be determined\(^1\).

### 3.3.2 Participants

The researchers then approached 154 schools throughout the Netherlands requesting the biology, chemistry and physics teachers to fill out the questionnaire online, using the collective educational research facility (CORF; www.corfstart.nl).

### 3.3.3 Analysis

Since the original emphasis questionnaire has been rephrased, coherence between the 46 items is analysed using a principal component analysis (pca). Items that are not correlating in their scales are excluded from further analysis, which adds to the instrument’s construct validity. For the thus created scales (one for each emphasis) Cronbach’s alpha, means and standard deviations are calculated.

Per scale the scores are calculated by taking the average of the answers to all corresponding statements. To determine whether there are significant differences between the average emphasis preferences within a subject and between subjects the scores are standardised (Z-score) to be able to calculate the distance from the general mean (all subjects combined per emphasis), expressed by the standardised standard deviation. The mathematical representation is given in Equation 1.

\[
Z = \frac{X - \overline{X}}{s}. \tag{3.1}
\]

Using a paired t-test significant differences among or between science subject are explored.

A Pearson correlation was used to analyse influences of age, teaching experience or design experience on the emphasis preferences of the science teachers.

\(^1\)The items of the rephrased questionnaire are presented in appendix D.
3.4 Results

3.4.1 Instrument

In the analysis of the scores from the emphasis questionnaire with the rephrased statements a Cronbach’s alpha of 0.76 (FS), 0.83 (KDS) and 0.91 (STS) for the original three emphasis scales was obtained. We conclude that the items despite the rephrasing are psychometrically sound to use the questionnaire among a larger group of participants.

In the second round 213 complete questionnaires were collected (57 biology, 61 chemistry and 95 physics).

The Kaiser-Meyer-Olkin test with KMO= 0.867 indicated a sufficient sample size to perform a pca. Bartlett’s test indicated that the correlations between the items were sufficient for a pca. An initial analysis was done to determine the eigenvalues of each data component. From the scree-plot (see Figure 3.1) we decided that three factors should be used for the analysis.

![Scree plot](image)

Figure 3.1: Scree plot

Repeating the pca with three factors gave a first indication of items per
scale. Next items with overlap between the three scales were excluded from further use. The remaining items thus divided into three scales represent the three emphases: FS, KDS and STS. For FS nine items (statements) remained, for KDS seven items and for STS twelve items. The results of the pca are depicted in appendix E. The reliability of the scales is still sound with Cronbach’s alpha ranging from 0.73 - 0.90. We conclude that the instrument measures the curriculum emphasis of science teachers (biology, chemistry and physics) reliably.

3.4.2 Score distribution

The scores on FS, STS and KDS have been tested for normality using a Kolmogorov-Smirnov test. The results are given in Table 3.3. For all three science subjects the FS scale has a normal distribution. The scales for KDS and STS are significantly not normally distributed, with $p < 0.05$ and $p < 0.01$. However, Levene’s test for homogeneity of variance between the groups was non-significant ($0.27 < p > 0.88$). This indicates that the emphasis preferences of biology, chemistry and physics teachers can be compared using a paired t-test.

<table>
<thead>
<tr>
<th></th>
<th>KS-Statistic</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>FS</td>
<td>Bio 0.103</td>
<td>58</td>
<td>0.193</td>
</tr>
<tr>
<td></td>
<td>Na 0.088</td>
<td>93</td>
<td>0.075</td>
</tr>
<tr>
<td></td>
<td>Sk 0.081</td>
<td>62</td>
<td>0.200*</td>
</tr>
<tr>
<td>KDS</td>
<td>Bio 0.122</td>
<td>58</td>
<td>0.031</td>
</tr>
<tr>
<td></td>
<td>Na 0.153</td>
<td>93</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Sk 0.171</td>
<td>62</td>
<td>0.000</td>
</tr>
<tr>
<td>STS</td>
<td>Bio 0.125</td>
<td>58</td>
<td>0.024</td>
</tr>
<tr>
<td></td>
<td>Na 0.119</td>
<td>93</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td>Sk 0.138</td>
<td>62</td>
<td>0.005</td>
</tr>
</tbody>
</table>

*This is the limit of true significance
Lilliefors significance correction

3.4.3 Scores per science subject

In Table 3.4 the Cronbach’s alpha for the new scales and the Z-scores of the different curriculum emphasis per subject are depicted.
3.4.4 Differences within and between the science subjects

Within the science subjects biology teachers have a significant preference for STS over FS ($t(57) = 4.2; p < 0.00; r = 0.49$). Also the preference of STS over KDS is significant ($t(57) = 5.2; p < 0.00; r = 0.66$). Chemistry teachers have no significant preference for one of the three curriculum emphases. Physics teachers have a strong preference for KDS over STS ($t(92) = 2.4; p < 0.02; r = 0.24$).

Between the subjects there is a significant difference in preference for an STS emphasis between biology teachers on the one hand and chemistry and physics teachers on the other ($t(149) = 4.2; p < 0.00; r = 0.33$ and $t(118) = 4.2; p < 0.00; r = 0.36$ respectively). We conclude that biology teachers have a stronger preference for an STS curriculum emphasis than chemistry or physics teachers.

3.4.5 Age, teaching experience and design experience

No significant correlation between age of the teacher and curriculum emphasis preference was found. Nor did the number of years of teaching experience correlate with a preference for any of the emphases. We conclude that neither with age nor with teaching experience an emphasis preference seems to arise with science teachers.

From the analysis no significant correlation was found between design experience and curriculum emphasis. We considered design experience with all kinds of instructional material. We conclude that with design experience no emphasis preference seems to arise with science teachers.
3.5 Conclusions and Discussion

The instrument used has proved to be reliable for the measurement of curriculum emphasis among biology, chemistry and physics teachers. The reliability coefficients found in this study are comparable to the ones reported by the authors of the original instrument, with Cronbach’s alpha between 0.71 - 0.82 (Van Driel et al., 2008, p 115). Calculated values of alpha per science subject (biology, chemistry and physics) are greater than 0.69. The reliability of the instrument is therefore comparable to that of Van Driel et al. (chemistry only). In view of the use of the same theoretical construct behind the statements and the (literally) parallel formulation of the statements it can be expected that the instrument used measures validly. Face validity was confirmed by a group of science teachers. When performing a pca on all items we obtained the result that the a priori scales are approximately reproduced, which supports construct validity. We conclude therefore that we have an instrument with parallel versions for the three different science subjects that has a comparable validity and reliability to the original instrument of (Van Driel et al., 2008).

The instrument aims at what can be called the general aspect of curriculum emphasis per science subject. Aspects of curriculum emphasis that are exclusive to one or more of the science subjects are not part of this instrument. This does not influence the comparability of the measured emphasis preferences. It does however, possibly make a concession to the completeness with which the emphasis preference for each of the three science subjects has been measured. Certain concepts exclusive to a specific science subject could have gone unmeasured.

In our research we used a non-selective sampling method (volunteers after telephone contact). Given the voluntary cooperation some distortion of the sample is possible. The sample however included people from both densely populated and less densely populated areas in the Netherlands, young and older teachers, men and women, and teachers with both few and many years of teaching experience. These background variables did not have any measurable influence on the emphasis preferences. We therefore assume our sample is representative for biology, chemistry and physics teachers in the Netherlands.

The results of our research show that within the different science subjects biology teachers have a preference for an STS emphasis. No significant preferences were found for chemistry teachers. Physics teachers prefer a KDS
emphasis over an STS emphasis. The widely vented opinion that chemistry teachers have a KDS preference and physics teachers an FS preference is not supported by our findings.

In the research by Van Driel et al. (2008) chemistry teachers have a significant preference for an FS emphasis. An explanation for this difference in results could be the demographical composition of the sample of the research by Van Driel et al. (2008) and this research. The study by Van Driel et al. was executed between 1999-2001, versus 2008 of our research. It is not unlikely that in seven years the ageing of the population has resulted in a number of ‘classic’ teachers leaving the occupation. Our result that emphasis preference does not correlate to age makes this explanation less likely however. Another explanation is the fast growing influence of the internet in recent years. New methods and techniques are disseminated more quickly and gain followers faster. Lastly, the movement that has risen around the chemistry innovation since 2003 can also have had its influence on the emphasis preference of chemistry teachers. This however, cannot be determined with this research.

Physics teachers appear to have a preference for a KDS emphasis over an STS emphasis. There is no indication that physics teachers have a preference for an FS emphasis. For physics there is a historic subject-specific pedagogic tradition to view ‘science as a process’ and to use scientific research methods (e.g. the work of PLON (Eijkelhof et al., 1986), the Nuffield Physics teaching method and ‘Physics is fun’), where the subject is treated (to a certain extent) as a non-societal domain. The emphasis preference found is in agreement with this: the way scientific knowledge is developed is more important than the social applicability of this knowledge.

From our research it appears that biology teachers have significantly stronger preference for an STS emphasis than either chemistry or physics teachers. This is probably related to the nature of the subject and the nature of the teaching material used. Biology is in essence suited to use the human being and its surroundings to give meaning to the concepts. The instructional materials available frequently provide these contexts.

The results give the impression that the emphasis preferences found for the three science subjects have an explicable relationship to the nature of the subjects and their pedagogic traditions. Moreover age, teaching
experience or design experience do not have an influence on curriculum emphasis. Influencing the emphasis preferences of teachers to make the pending context-based innovation successful seems therefore possible if it is channelled though the subjects’ pedagogy. More research is required to elaborate on these possibilities.

Pajares (1992) states that the beliefs a teacher has on education are the largest influence on what happens in the classroom, something Roberts (1988) calls a conflict of loyalties between the materials intended curriculum emphasis and the teachers preference. From this research it appears the reigning impression that science teachers have an FS curriculum emphasis preference can be nuanced. Biology teacher prefer an STS emphasis and physics teachers a KDS emphasis (with FS preference not significantly lower). Chemistry teachers show a mixed preference with a non-significant preference for FS. The probability of a conflict of loyalties between the emphasis preference of science teachers and the KDS or STS emphasis necessary for the pending context-based curriculum innovation is lower for biology than for chemistry.
Chapter 4

Measuring context-based learning environments in Dutch science classrooms


4.1 Introduction

A common trend in high school science education is to adopt the context-based pedagogical approach (Pilot & Bulte, 2006a). This approach has been chosen since it is expected to assist in creating more interest among students to pursue a scientific higher educational career (Gilbert, 2006). In this chapter we address the characteristics of a context-based learning environment (CBLE) from both the student and the teacher’s perspective and how we can measure these characteristics in the classroom. Learning environment research can and has been used to evaluate interventions, such as curriculum reforms (Goh & Khine, 2002), and is thus suitable for our purpose to evaluate a CBLE.

In the Netherlands the innovation committees for the curriculum innovation of the high school science subjects, biology, chemistry and physics included this approach in their respective vision documents (Boersma et al., 2007; Commissie Vernieuwing Natuurkunde Onderwijs HAVO/VWO [Innovation committee high school physics education], 2006; Driessen & Meinema, 2003).
The committees have been instructed to reduce the overload of the current science curricula and to incorporate modern scientific knowledge and developments in the curricula.

The committee for the new science subject advanced science, mathematics, and technology (ASMaT) also advocates the context-based approach in the curriculum (Steering Committee Advanced Science, Mathematics and Technology, 2008). The committees instigated the design of test-materials to try out a new context-based curriculum. Teachers will need to adopt a context-based teaching approach to make the innovation a success. When teachers do not adopt the innovation it will fail (Fullan, 1994). However, the context-based approach is not new to Dutch high school educational materials. The approach and materials have been elaborated on for different year levels in the seventies for chemistry, mathematics and physics (Hooymayers, 1986; Boersma, 1987; Hondebrink, 1987). Implementing the context-based innovation in the science subjects could therefore be less of a challenge than would generally be expected (Fullan, 1994). The use of contexts has been incorporated in the state exam questions for the science subjects since the eighties and, in a far lesser extent, science textbooks have incorporated applications of scientific concepts in each chapter (either as a final paragraph, or throughout the paragraphs were applicable). Hence the context-based approach—in a basic form—is likely to be present in Dutch science classrooms and known to science teachers.

To reveal to what extent teachers realise a CBLE with the current materials and the (upcoming) innovative materials we need tools for monitoring the resulting CBLE. Our research focuses on the behavioural aspects of CBLE’s already present in Dutch science classrooms to establish how much of a change the innovation would be to science classes.

In our research we will develop and validate a teacher and student questionnaire to evaluate the current context-based science learning environment.

4.2 Context-based learning environment and behaviour

The nature of the contexts used in context-based chemistry education has been described in detail by Gilbert (2006). Continuing from the descriptions given in his article and applying them to science education, contexts should have:

a setting within which mental encounters […] with focal events are situated; a behavioural environment of the encounters, the
way that the task(s), related to the focal event, have been addressed, is used to frame the talk that then takes place; the use of specific language, as the talk associated with the focal event that takes place; a relationship to extra-situational background knowledge (Duranti & Goodwin, 1992, p. 6-8).

Context-based science education thus relies on a constructivist dimension that the content should be within the horizon of the learner (Labudde, 2008). Waddington (2005) concludes that many forms of context-based education are constructivist in nature.

In a constructivist view on learning Labudde (2008) distinguishes four dimensions. The first dimension he distinguishes concerns the individual, i.e. knowledge is a construction of the individual learner. A consequence of this is that what an individual learns is not an exact copy of outside reality, but coloured with the pre-existing knowledge, beliefs and interpretation of the individual.

The second dimension concerns social interactions, i.e. the knowledge construction occurs in exchange with other people. The description of the exchange can be moderated to a more co-constructing of knowledge, where students among themselves or in talks with their teacher establish a knowledge base.

The third dimension concerns the content. “If learning is an active process of constructing new knowledge based on existing knowledge [...] then the contents to be learned must be within the horizon of the learner” (Labudde, 2008, p. 141). This is stressed in the definition of Bennett et al. (2007) in their review of research on context-based education: “Context-based approaches are approaches adopted in science teaching where contexts and applications of science are used as the starting point for the development of scientific ideas. This contrasts with more traditional approaches that cover scientific ideas first, before looking at applications” (Bennett et al., 2007, p. 348).

In this study the handling of contexts (by the teacher), the establishment of scientific concepts and transferring of the concepts to other contexts is referred to as context and transfer. To include contexts in the learning environment the teachers are required to be capable to familiarise themselves with the main context used in class and to: “[...] bring together the socially accepted attributes of a context and the attributes of a context as far as these are recognised from the perspective of the students” (Gilbert, 2006, p. 965). This differs from traditional education where the concepts are important and usually explained first before embarking on applications.
The context should cause a need for students to explore and learn concepts and to apply them to different situations. Teachers have to be able to establish basic scientific concepts through context-based education (Parchmann et al., 2006) and have to be aware of the need for concept transfer (to other contexts) (Van Oers, 1998).

The fourth dimension of a constructivist view on learning concerns the teaching methods, i.e. the role of the teacher. Labudde (2008) concludes that

[...] the learning process of the individual and the co-construction of new knowledge can be to some extent be supported by ex-cathedra teaching and classroom discussions. But for promoting learning as an active process and for stimulating the co-construction of knowledge other teaching methods seem to be more suitable, e.g. students’ experiments and hands-on activities, learning cycles, project learning or case studies (p. 141).

“Students’ experiments, hands-on activities and project learning” can be characterised as student active learning or student self-regulated learning. According to Vermunt and Verloop (1999) such learning calls for specific teaching activities. They categorise activities in three categories: strong, shared and loose teacher control. To achieve the desired intermediate or high degree of self-regulated learning a shared or loose control strategy by the teacher is called for. Teaching activities to support a shared control strategy include: having students make connections with their own experiences, giving students personal responsibility for their learning, giving students freedom of choice in subject matter, objectives and activities, having students tackle problems together (Vermunt & Verloop, 1999). Teachers should be competent in controlling these kinds of activities, i.e. to guide rather than control the learning process of the students. Students in turn should experience this kind of regulation. In a CBLE students are required to have a sense of ownership of the subject and are responsible for their own learning (Gilbert, 2006; Parchmann et al., 2006). As current research in science education points out: people construct their own meanings from their experiences, rather than acquiring knowledge from other sources (Bennett, 2003). Hence context-based education should honour the fourth constructivist dimension that the students are responsible for their own learning that is best fostered using a coaching teaching style (Labudde, 2008).
The combination of a shared control teaching strategy and the subject of the content to be learned being 'within their horizon' also demands a change in teaching emphasis. For context-based education this has been defined by using the emphasis definition suggested by Roberts (1982):

A curriculum emphasis in science education is a coherent set of messages to the student about science [. . .]. Such messages constitute objectives which go beyond learning the facts, principles, laws, and theories of the subject matter itself - objectives which provide answers to the student question: “Why am I learning this?” (p. 245).

Van Berkel (2005) and Van Driel et al. (2008) contracted Roberts’ original seven emphases to three for chemistry. De Putter-Smits et al. (2011) reverted these to ‘science’ emphases and used the following three definitions:

The first of the curriculum emphases is fundamental science (FS) where the scientific theories are taught first, because it is believed that this knowledge forms a fundamental base to understand the world, and that this knowledge is necessary for the students’ further education. The second curriculum emphasis is knowledge development in science (KDS) where students learn how scientific knowledge is developed in the socio-historic contexts. In this way they learn that science is a culturally determined knowledge system that evolves continuously. The third curriculum emphasis is science technology and society (STS) where students are expected to be able to communicate about and make decisions on subjects from society that have scientific aspects (De Putter-Smits et al., 2011).

From the literature it is apparent that a KDS or an STS teaching emphasis is an important success factor for the context-based innovation (Driessen & Meinema, 2003; Gilbert, 2006).

Three context-based learning environment characteristics have been described (context and transfer, regulation, and emphasis). In a previous study we identified five characteristics (De Putter-Smits et al., in pressb). However, for this study we use the characteristics most visible in classrooms, to be able to obtain also a student perception of the learning environment a teacher is able to create. A context-based learning environment therefore is an approach with a constructivist view on learning that supports students
responsibility for their own learning, that uses the context as a vehicle for establishing concepts, and that has a teaching emphasis appropriate to the use of contexts, abbreviated to the three CBLE characteristics (see scheme in Figure 4.1). Since we are interested in the classroom realisation by the teacher of these characteristics we narrow our view to teacher behaviour, both from the teachers’ as their students’ perceptions.

Figure 4.1: Model used for context-based learning environments

4.2.1 Research questions

The research questions addressed in this study are:

1. How can we measure the three characteristics of a context-based learning environment as presented above in a reliable and valid manner?

And if we can:

2. What are the differences in context-based learning environment in Dutch senior high schools between the different science subjects?
3. What are the differences in context-based learning environment in Dutch senior high schools among specific groups of teachers, such as:

   • teachers with context-based or other study material design experience compared to teachers without this experience;
   • teachers who use context-based materials in class compared to teachers who do not.
4.3 Measurement of context-based science learning environments

In search of established instruments we could use to measure the typical characteristics of the CBLE in science classrooms, we made use of the parallels of CBLE and constructivist learning environments. To measure constructivist learning environments Taylor et al. (1993, 1997) have constructed the ‘constructivist learning environment survey’ (CLES). The CLES originally consisted of 30 items divided into five scales: personal relevance, uncertainty, critical voice, shared control, and student negotiation. The CLES was shortened and re-evaluated by Johnson and McClure (2004). The CLES has been widely used and reported on. The successful use in science classes is reported by Aldridge, Fraser, Taylor, and Chen (2000); Roth and Bowen (1995); Lucas and Roth (1996). Not all scales in the CLES are relevant to a context-based science learning environment. From the scale definitions (scale definitions for CBLEs are presented in Table 4.1) we select the personal relevance scale as an indicator for the use of contexts (close to the horizon of the learner) in the classroom. A typical item in this scale is: “New learning relates to experiences or questions about the world inside and outside of school” (Johnson & McClure, 2004, p. 77). All items in this scale relate to the connection between the outside world and the learning of scientific ideas. We believe that the uncertainty scale of the revised CLES is an indicator for a KDS emphasis. This scale establishes to which extent student knowledge is developed from a socio-historic perspective. A typical example of the items in this scale is: “Students learn that science is influenced by people’s cultural values and opinions” (Johnson & McClure, 2004, p. 78). To measure the teacher regulation in context-based classrooms we selected the student negotiation and learning to learn scales from the revised CLES (Johnson & McClure, 2004). Sample items of the items in these scales are: “Students explain their ideas to other students” and “Students help me plan what they are going to learn” (Johnson & McClure, 2004, p. 78).

Another instruments that measures learning environments in (science)

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1 Considering the practical argument that long questionnaires might be filled in less seriously by students, the version of the CLES constructed by Johnson and McClure (2004) was chosen.

2 Originally this scale is called ‘shared control’, however due to the similar name of the QIB scale, another term for this scale that is mentioned in Johnson and McClure (2004) was used.
classrooms is the ‘what is happening in this classroom’ questionnaire (WHIC), constructed by (Fraser et al., 1996). This questionnaire was constructed by “combining salient scales from existing questionnaires” (Dorman, 2003, p. 233) and contains 56 items in seven scales (student cohesiveness, teacher support, involvement, investigation, task orientation, cooperation, and equity). Of the seven scales we expect the investigation scale to relate to a KDS emphasis, where students learn how scientific knowledge is derived from research. A sample item in this scale is formulated as: “I carry out investigations to test my ideas” (Dorman, 2003, p. 234).

To measure the regulation aspect of learning environments Lamberigts and Bergen (2000) developed the Questionnaire on Instructional Behaviour (QIB). The questionnaire consists of 33 items in five scales: clarity, classroom management, strong control, shared control and loose control. The QIB has been used effectively in Dutch secondary (science) education by (Den Brok et al., 2006). From this questionnaire we select three scales that address strong, shared and loose teacher control (12 items). Typical items include: “S/he stimulates us to help each other when working on a task” and “S/he lets us determine our own pace in working on tasks” (Den Brok et al., 2006, p. 135).

To measure the elements of a CBLE we described earlier, we have identified eight possible scales (see Table 4.1): one to measure context-handling, two to measure emphasis and five to measure regulation. Unfortunately no questionnaire scale has as yet been constructed to measure the aspect of concept transfer (Van Oers, 1998) that is an important element of a CBLE.
Table 4.1: Proposed scales to measure a context-based learning environment

<table>
<thead>
<tr>
<th>Scale</th>
<th>Definition</th>
<th>CBLE scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal relevance$^2$</td>
<td>Extent to which school science is relevant to students’ everyday out-of-school experiences</td>
<td>Context and transfer</td>
</tr>
<tr>
<td>Investigation$^1$</td>
<td>Extent to which there is emphasis on skills and inquiry and their use in problem solving and investigation in a classroom</td>
<td>Emphasis</td>
</tr>
<tr>
<td>Uncertainty$^2$</td>
<td>Extent to which opportunities are provided for students to experience that scientific knowledge is evolving and culturally and socially determined</td>
<td>Emphasis</td>
</tr>
<tr>
<td>Learning to learn$^2$</td>
<td>Extent to which students have opportunities to explain and justify their ideas, and to test the viability of their own and other students’ ideas</td>
<td>Regulation</td>
</tr>
<tr>
<td>Student Negotiation$^2$</td>
<td>Extent to which students share with the teacher control for the design and management of learning activities, assessment criteria, and social norms of the classroom</td>
<td>Regulation</td>
</tr>
<tr>
<td>Strong control$^3$</td>
<td>Extent to which students are provided with strategies to perform their learning activities</td>
<td>Regulation</td>
</tr>
<tr>
<td>Shared control$^3$</td>
<td>Extent to which students share the responsibility among themselves and with the teacher</td>
<td>Regulation</td>
</tr>
<tr>
<td>Loose control$^3$</td>
<td>Extent to which students make their own decisions during the performance of learning activities</td>
<td>Regulation</td>
</tr>
</tbody>
</table>

$^1$ Dorman (2003, p. 234); $^2$ Johnson and McClure (2004, p. 68); $^3$ Den Brok et al. (2006)
4.4 Construction and Pilot

On the basis of our literature review we combined scales from ‘WIHIC’, ‘CLES’, and ‘QIB’ into a new instrument we named WCQ after its parent questionnaires. The WCQ contains 36 items divided in eight scales. All original questionnaires used a five-point Likert-scale ranging from ‘I do not agree at all’ to ‘I agree completely’. Combining the questions therefore did not result in re-scaling issues.

As described we aim at two versions of the WCQ, one for teachers and one for their students. Not all questionnaires were phrased from both student and teacher perspective. We translated the questions into Dutch and where necessary rephrased the questions to represent either the student’s or the teacher’s point of view. In the introduction to the questionnaires the students (or teachers) were requested to fill out the questions for [subject] taught by [name] teacher, to avoid a general opinion on the teacher or the subject being given.

The two questionnaires (named WCQ-teacher and WCQ-student) were then tested in a pilot study on context-based teaching competencies of teachers that use context-based materials in class. In the pilot study (reported on earlier in (De Putter-Smits et al., in pressb)) the reliability and validity of the WCQ-questionnaires was addressed.

To be able to measure more of the context and transfer competency an attempt was made to construct a concept transfer scale. With the input of two science teachers and two researchers a list of 14 items was constructed that inquire after the transfer of scientific concepts. A typical example of these transfer items is: “Students learn how to recognise a scientific concept they have learned in a different context”. Due to the displaced time frame of the research we relied on a second short pilot study to analyse this scale for reliability and validity.

4.4.1 First pilot

4.4.1.1 Method

For the pilot study we sought teachers with a varying extent to which their classrooms were expected to be CBLE. By varying the expected CBLE the instrument can be tested thoroughly: higher scores would then be indicative of a more context-based classroom facilitating the establishment of construct validity. The pilot study comprised of more data sources such
as semi-structured interviews and classroom observations. Each context-based characteristic had at least two other sources besides the corresponding WCQ-scales. Validity of the WCQ was addressed in two ways. First, scales not measuring consistently with other data sources were analysed and improved or removed from the questionnaire. This was done by correlating the scores per WCQ scale with other data sources that are expected to measure the same construct. For instance, when a teacher has an above average score for shared regulation, the classroom observation of this teacher should be exemplary of this kind of teaching. Correlations higher than 0.35 were taken as an indication that the construct was measured by the methods correlated (questionnaire scale with classroom observation, interview question with questionnaire scale etc.), thus confirming validity of the instrument. Second, a confirmative factor analysis was performed to ensure the items fit in their expected scales.

The reliability for the WCQ-teacher and student questionnaire was addressed by comparing the Cronbach’s alpha’s obtained for the eight scales in the pilot with the reported reliability coefficients of the original scales of the questionnaires used.

4.4.1.2 Result

Ten teachers (one physics, three chemistry, five ASMaT, and one biology) varying in the extent to which their classrooms were expected to be CBLE’s and 162 of their students joined our pilot study and filled out the WCQ questionnaire.

Reliability data on items in their original scales are provided in Table 4.2. The scores for the CLES scale personal relevance for both the student and teacher WCQ questionnaire correlated sufficient with other pilot-study data, a teacher interview and classroom observation (0.46 < r < 0.97). An exploratory factor analysis (Varimax with Kaiser normalization; KMO test 0.88) shows correlations between QIB strong control and CLES learning to learn indicating that students and teachers do not experience to be free to test their own ideas. This was confirmed by the other data sources in the pilot, showing substantial correlations between the QIB-scales shared control and loose control, student negotiation and interviews and observations, but low correlation with the learning to learn scale. Combining these effects leads us to conclude that the CLES learning to learn scale should be removed from the questionnaire. The factor analysis showed that all items
fit well in their respective scales. The validity of the remaining scales was thus confirmed.

<table>
<thead>
<tr>
<th>Scale</th>
<th>No. of items</th>
<th>Original Alpha</th>
<th>Pilot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal relevance</td>
<td>4</td>
<td>0.90</td>
<td>0.85</td>
</tr>
<tr>
<td>Investigation</td>
<td>8</td>
<td>0.85</td>
<td>0.83</td>
</tr>
<tr>
<td>Uncertainty</td>
<td>4</td>
<td>0.81</td>
<td>0.75</td>
</tr>
<tr>
<td>Learning to learn</td>
<td>4</td>
<td>0.85</td>
<td>0.75</td>
</tr>
<tr>
<td>Student negotiation</td>
<td>4</td>
<td>0.91</td>
<td>0.87</td>
</tr>
<tr>
<td>Strong control</td>
<td>3</td>
<td>0.83</td>
<td>0.78</td>
</tr>
<tr>
<td>Shared control</td>
<td>6</td>
<td>0.82</td>
<td>0.81</td>
</tr>
<tr>
<td>Loose control</td>
<td>3</td>
<td>0.86</td>
<td>0.78</td>
</tr>
</tbody>
</table>

| N                          | 3980,354,1676³ | 173           |
| Teachers                   | 72³           | 10            |
| Students                   | 3980,354,1604³ | 163           |

¹Dorman (2003, p. 234); ²Johnson and McClure (2004, p. 68); ³Den Brok et al. (2006)

For the CBLE constructs emphasis and regulation the reliability coefficients for all items concerned were 0.86 and 0.90 respectively. The QIB scale strong control is linked to the other two QIB scales in that it does not measure the opposite construct (cf. Den Brok et al., 2006). This effect is not apparent when correlating scores with other data such as interviews and classroom observations, where a negative correlation is obtained. We concluded that the QIB strong control scale should be removed from the questionnaire to ensure we measure the regulation construct consistently.

Comparing the WCQ student scores with their teachers’ scores revealed differences for some teachers. Two teachers expected to score high on the WCQ were given low scores by their students. Other data sources indicated that the teachers were cognitively well aware of what a CBLE entailed, but their students did not experience this. Two teachers expected to score high in the WCQ scored similar to their students, one teacher-and-class scored extremely high (4.0-4.5 on a Likert scale), one more average (2.8-3.5 on a Likert-scale). The teachers that were not expected to score high, scored average (2.8-3.5 on a Likert-scale).
4.4.2 Second pilot -transfer scale

A small pilot was conducted for these 14 items among 66 students from two science teachers, one reading chemistry, the other reading physics. A principal component analysis (KM-test indicated adequate sample size) revealed three possible transfer sub-scales. One to be interpreted as ‘activating previous knowledge’, one as ‘coherence of concepts within the subject’ and one ‘using concept learned in new context’. It also revealed two questions needed to be rephrased as they had smaller correlations in their scales. These questions were found difficult to interpret by the students, judging from the remarks on the filled in questionnaires. One question was considered similar to another question (correlation of almost one) and has been omitted. In all 13 transfer items were added to the revised WCQ questionnaire (see Figure 4.2).

![Figure 4.2: Scheme for the revised WCQ](image)

4.5 Experiment

4.5.1 Experiment -method

After the evaluation and improvement of the WCQ-questionnaires in the pilot studies we conducted a larger experiment, using the WCQ only. By obtaining a large collection of WCQ data we tried to identify differences in CBLE between the different science subjects and between teachers and classrooms with different characteristics, such as design-experience or use
of innovative context-based material.

We approached all high school listed on the governmental website (1133) throughout the Netherlands by phone and email to obtain their cooperation. Teachers (and their students) who agreed to join the study completed the questionnaire either online through the collective education research facility CORF (www.corfstart.nl) or on paper.

The data obtained were analysed for reliability of the scales. Scales expected to measure the same construct are expected to show high correlations. A confirmative factor analysis (cfa) was performed to confirm the scale items. To test our model nesting our separate WCQ scales under three CBLE scales (Figure 4.2) we used multiple indices to assess adequateness of fit (Tabachnick & Fidell, 1997): the Chi-square test of model fit ($\chi^2$) the comparative fit index (CFI), the Tucker-Lewis index (TLI), and the standard root mean square residual (SRMR).

With the model confirmed we then calculated the three context-based scale scores (context-handling, regulation and emphasis) to address the remaining research questions. An analysis of variance with appropriate post-hoc tests (Hochberg vis. Games-Howell) was used in the analysis of teacher and student scores on the different context-based scales to answer the second research question on possible differences per science subject. The third research question was answered by performing a similar analysis considering the background characteristic of the teacher, i.e. context-based or other material design experience and teaching using context-based curriculum materials. To this end, two open ended questions were added to the questionnaires. One inquiring after the material the teacher used in class and one whether the teacher had (ever) designed curriculum materials and if so to elaborate on the nature of these curriculum materials. The researchers then converted the answers given into three options. For design experience these were: none, general subject related material design (experiments, additional concept clarifications etc.) and context-based material design. For teaching using context-based materials in class they were: only standard book (containing context-references), mixed innovative context-based materials and standard book, and only the innovative context-based material. The influences of the science subject, design experience and teaching using context-based materials on the scores are also analysed for their possible
interactions.

4.5.2 Experiment -results

The validated and revised WCQ questionnaire, now containing the transfer -items (see method section), was filled out by 15 ASMaT teachers and 153 ASMaT students, 26 physics teachers and 452 physics students, 24 chemistry teachers and 530 chemistry students, and 23 biology teachers and 424 biology students. In all, 1630 usable questionnaires were obtained.

All students were from years 10-12 from senior general secondary education and pre-university education. Unfortunately no information on the gender of the students and teachers was available. The teachers varied in years of teaching experience from one year to 40 years. Of the respondents 45% attended rural high schools and 55% attended urban high schools (30 largest cities in the Netherlands).

The conversion of the kind of curriculum materials and the design experience into the three respective categories was done by two researchers independently, reaching full agreement. The possible extra category of teachers having both design experience in standard curriculum materials and context-based materials was not found.

To answer our first research question we performed a confirmative factor analysis. This revealed two items should be removed from the questionnaire (due to the much larger sample); one from the investigation scale, one from the student negotiation scale. The second order factor analysis confirmed the three context-based scales we predicted from literature (see Figure 4.2). The RMSEA for this model was 0.044, which indicated a good fit of our model. The \( \chi^2 \)-test was significant (F=2623, df=655, \( p < 0.00 \)). However, since our data set has a large number of respondents (n=1630) this is not an indication that the model is inadequate (Brannick, 1995). The CFI and the TLI were 0.92 and 0.91 respectively, which indicates a reasonable fit of our model. The SRMR was 0.046 indicating a good fit of our model. This analysis confirms that the three context-based constructs we identified are measured with this questionnaire.

To ensure all scales together indeed form a coherent measurement of the learning environment, we also performed a second-order cfa with one general context-based scale as a second order construct over the original WCQ scales (see Figure 4.1). This resulted in a reasonable fit for the model (RMSEA=0.047, CFI-TLI=0.91-0.90, SRMR=0.051) confirming our instrument coherently measures the context-based learning environment as expected.
The reliability coefficients for the various scales thus confirmed are given in Table 4.3.

### Table 4.3: Reliability coefficients for the revised WCQ scales and context-based scales

<table>
<thead>
<tr>
<th>Scale</th>
<th>Teachers</th>
<th>Students</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Alpha</td>
<td>n</td>
<td>Alpha</td>
</tr>
<tr>
<td>Investigation</td>
<td>0.86</td>
<td>86</td>
<td>0.83</td>
</tr>
<tr>
<td>Personal relevance</td>
<td>0.87</td>
<td>83</td>
<td>0.81</td>
</tr>
<tr>
<td>Uncertainty</td>
<td>0.75</td>
<td>88</td>
<td>0.71</td>
</tr>
<tr>
<td>Student negotiation</td>
<td>0.89</td>
<td>88</td>
<td>0.87</td>
</tr>
<tr>
<td>Shared control</td>
<td>0.70</td>
<td>88</td>
<td>0.76</td>
</tr>
<tr>
<td>Loose control</td>
<td>0.74</td>
<td>88</td>
<td>0.74</td>
</tr>
<tr>
<td>Transfer</td>
<td>0.87</td>
<td>88</td>
<td>0.91</td>
</tr>
<tr>
<td>Context and transfer</td>
<td>0.85</td>
<td>87</td>
<td>0.91</td>
</tr>
<tr>
<td>Regulation</td>
<td>0.82</td>
<td>88</td>
<td>0.85</td>
</tr>
<tr>
<td>Emphasis</td>
<td>0.84</td>
<td>86</td>
<td>0.83</td>
</tr>
<tr>
<td>Total context-based</td>
<td>0.89</td>
<td>86</td>
<td>0.93</td>
</tr>
</tbody>
</table>

The WCQ constructs *context and transfer*, *emphasis*, *regulation* and the *total context-based* construct show comparable reliability coefficients for the cases per science subject (see Table 4.4) making the scores per subject comparable. This allows us to answer our second research question using the three composite scales only.

Though the data distribution shows a mild kurtosis (including per science subject), the sample size (for students) is large enough to conclude that the data can be treated as normally distributed, which allows for use of ANOVA procedures.

**Comparing the science subjects with each other** The average teacher WCQ-scores and standard deviations per subject are presented in Figure 4.3. A one-way ANOVA with the scores on context-and-transfer, regulation, emphasis and the total context-based as dependent variables and science subject as factor, revealed a significant difference between the subjects on the *emphasis* and *total context-based* scales with $F(3, 84) = 3.32$, $p < 0.05$, $\omega^2 = 0.073$ and $F(3, 84) = 3.49$, $p < 0.05$, $\omega^2 = 0.078$ respectively. In terms of effect size this is effect is medium (Kirk, 1996). A post-hoc Hochberg test (for unequal sample sizes) indicated that the ASMaT teach-
Table 4.4: Reliability coefficients for context-based learning environment scales per science subject

<table>
<thead>
<tr>
<th>Teachers</th>
<th>Scale</th>
<th>ASMaT Alpha</th>
<th>n</th>
<th>Biology Alpha</th>
<th>n</th>
<th>Chemistry Alpha</th>
<th>n</th>
<th>Physics Alpha</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Context and transfer</td>
<td>0.83</td>
<td>15</td>
<td>0.89</td>
<td>23</td>
<td>0.88</td>
<td>23</td>
<td>0.80</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>Regulation</td>
<td>0.76</td>
<td>15</td>
<td>0.77</td>
<td>23</td>
<td>0.81</td>
<td>24</td>
<td>0.84</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>Emphasis</td>
<td>0.83</td>
<td>15</td>
<td>0.70</td>
<td>22</td>
<td>0.88</td>
<td>23</td>
<td>0.84</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>Total context-based</td>
<td>0.86</td>
<td>15</td>
<td>0.82</td>
<td>22</td>
<td>0.92</td>
<td>23</td>
<td>0.89</td>
<td>26</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Students</th>
<th>Scale</th>
<th>ASMaT Alpha</th>
<th>n</th>
<th>Biology Alpha</th>
<th>n</th>
<th>Chemistry Alpha</th>
<th>n</th>
<th>Physics Alpha</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Context and transfer</td>
<td>0.92</td>
<td>147</td>
<td>0.91</td>
<td>395</td>
<td>0.91</td>
<td>503</td>
<td>0.90</td>
<td>415</td>
</tr>
<tr>
<td></td>
<td>Regulation</td>
<td>0.87</td>
<td>152</td>
<td>0.83</td>
<td>419</td>
<td>0.85</td>
<td>521</td>
<td>0.85</td>
<td>431</td>
</tr>
<tr>
<td></td>
<td>Emphasis</td>
<td>0.84</td>
<td>149</td>
<td>0.80</td>
<td>418</td>
<td>0.82</td>
<td>515</td>
<td>0.84</td>
<td>443</td>
</tr>
<tr>
<td></td>
<td>Total context-based</td>
<td>0.94</td>
<td>145</td>
<td>0.92</td>
<td>389</td>
<td>0.93</td>
<td>480</td>
<td>0.93</td>
<td>399</td>
</tr>
</tbody>
</table>

Teachers score their learning environment significantly more context-based than the physics teachers on these scales ($p < 0.05$).

The average student WCQ-scores are shown in Figure 4.3. For the students’ scores the difference between the subjects is significant (one-way ANOVA) for all CBLE scales (F-values in Table 4.5). In terms of effect size these effects are small (Kirk, 1996).

A post-hoc Games-Howell test (for large sample sizes Field (2005)) for the *context and transfer* scale indicated that biology, chemistry and physics students score the learning environment they experience significantly more context-based than ASMaT students.
Means for Context and Transfer

Figure 4.3: Representation of the differences in WCQ-scores between teachers and students

Table 4.5: Significant differences in teacher and student scores comparing science subjects; F-values and $\omega^2$

<table>
<thead>
<tr>
<th>Scale</th>
<th>Teachers</th>
<th>$\omega^2$</th>
<th>Students</th>
<th>$\omega^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Context and transfer</td>
<td>n.s.</td>
<td>6.55 (3, 1559)</td>
<td>0.011</td>
<td></td>
</tr>
<tr>
<td>Regulation</td>
<td>n.s.</td>
<td>23.24 (3, 1555)</td>
<td>0.041</td>
<td></td>
</tr>
<tr>
<td>Emphasis</td>
<td>3.32 (3, 84)</td>
<td>0.073</td>
<td>13.32 (3, 1568)</td>
<td>0.023</td>
</tr>
<tr>
<td>Total context-based</td>
<td>3.49 (3, 84)</td>
<td>0.078</td>
<td>12.93 (3, 1569)</td>
<td>0.022</td>
</tr>
</tbody>
</table>

with $p < 0.05$
For the emphasis scale, the post-hoc Games-Howell test indicated that chemistry students score their learning environment significantly more context-based than ASMaT and physics students on this scale. Furthermore, biology students score significantly higher than physics students (All F-values presented in Table 4.5).

The post-hoc test indicated for the regulation scale that ASMaT, biology, and chemistry students score their learning environment significantly more context-based than physics students.

The post-hoc test for the total context-based scale indicated that chemistry students score their learning environment significantly more context-based than physics students on this scale. Biology students scored significantly more context-based than ASMaT and physics students.

Figure 4.3: Representation of the differences in WCQ-scores between teachers and students -continued
Figure 4.3: Representation of the differences in WCQ-scores between teachers and students -continued
Comparing teacher and student scores As can be seen in Figure 4.3 it is apparent that the largest difference in opinion between teachers and students occurs for context and transfer (which influences the total context-based score). The teachers are very optimistic compared to their students. It is therefore difficult to determine what the learning environment for the different subject actually looks like. Calculating the general differences between teachers and students the teachers describe the learning environment they create significantly more context-based than their students for context and transfer and regulation (with $F(1,1649) = 12.53$, $p < 0.00$, $\omega^2 = 0.007$ and $F(1,1645) = 10.31$, $p < 0.00$, $\omega^2 = 0.006$ respectively). They are less optimistic than their students about the learning environment related to emphasis (with $F(1,1658) = 14.98$, $p < 0.00$, $\omega^2 = 0.008$). All effect sizes are small.

This trend continues per science subject with ASMaT teachers scoring the learning environment they create more context-based on context and transfer, regulation, and total context-based (with $F(1,166) = 11.78$, $p < 0.01$, $\omega^2 = 0.060$; $F(1,166) = 5.88$, $p < 0.05$, $\omega^2 = 0.028$; and $F(1,166) = 6.36$, $p < 0.05$, $\omega^2 = 0.031$ respectively). Biology, chemistry, and physics teachers score the learning environment they create less context-based on emphasis (with $F(1,445) = 7.35$, $p < 0.01$, $\omega^2 = 0.014$; $F(1,565) = 4.50$, $p < 0.05$, $\omega^2 = 0.006$; and $F(1,476) = 7.11$, $p < 0.01$, $\omega^2 = 0.013$ respectively). Physics teachers score the learning environment they create more context-based on regulation (with $F(1,472) = 4.65$, $p < 0.05$, $\omega^2 = 0.008$). All effect sizes are small.

Comparing background characteristics of teachers Our third research question concerned the background characteristics of teachers: the (context-based) design experience and the materials used in class (standard book, mixed materials and context-based materials only). Teachers with (context-based) design experience have no significant different WCQ scores from teachers without this experience.

Students score the learning environment they experience for teachers with (any) design experience more context-based than students from teachers without this experience (see Table 4.6). The effect sizes are small. Design experience in subject related material has more influence on the WCQ scores than context-based design experience (see Figure 4.4). This trend is visible for all science subjects apart from ASMaT, where (any) design
experience has a negative influence on the WCQ student scores (see Figure 4.5). From Figure 4.5 it is apparent that for biology there are no teachers with ‘design experience in subject related material’ in our sample.

Table 4.6: Influences on student WCQ scores: design experience and method (F, df, and $\omega^2$)

<table>
<thead>
<tr>
<th>Scale</th>
<th>Design experience</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>df</td>
</tr>
<tr>
<td>Context and transfer</td>
<td>3.92</td>
<td>(2, 1546)</td>
</tr>
<tr>
<td>Regulation</td>
<td>4.87</td>
<td>(2, 1542)</td>
</tr>
<tr>
<td>Emphasis</td>
<td>n.s.</td>
<td></td>
</tr>
<tr>
<td>Total context-based</td>
<td>4.06</td>
<td>(2, 1556)</td>
</tr>
</tbody>
</table>
From the analysis for the materials used in class (standard text book, mixed materials, context-based materials only) a significant test result from the teachers’ perspective was obtained for all CBLE scales. A post-hoc Hochberg test indicated that for all four context-based scales students who use mixed-materials scored significantly higher than those who use a standard book. Also the use of context-based material scored significantly higher on the scales for regulation, emphasis, and total context-based than the use of a standard book. For the context and transfer scale $F(2, 84) = 4.21 (p < 0.05)$ with $\omega^2 = 0.069$, for the regulation scale $F(2, 84) = 5.95 (p < 0.01)$, with $\omega^2 = 0.10$, and for the emphasis scale $F(2, 84) = 6.39 (p < 0.01)$, with $\omega^2 = 0.11$. In terms of effect size these effects are medium. On the total context-based scale $F(2, 84) = 9.81 (p < 0.00)$ with $\omega^2 = 0.17$, which is a large effect size.

The corresponding analysis on the student data revealed significant results for all CBLE scales (see Table 4.6 and Figure 4.6). When mixed materials are used in class the scores on all CBLE scales are significantly higher than either for when context-based materials only are used or when a standard book is used. For the regulation scale the use of context-based materials has a significant effect on the WCQ score in preference to the use of a standard book. For the context and transfer scale the use of context-based materials only has a significant negative difference in WCQ score versus the use of a standard book.

To eliminate the possibility that this effect is due to the nature of the subject taught (biology, chemistry and physics\(^1\)) we used subject as covariate in an ancova. Similar results were obtained with the differences significant with $p < 0.01$). The student WCQ scores per subject per scale are given in Figure 4.7.

\(^1\)For ASMaT, only context-based materials are available
Figure 4.5: Student scores separated by design experience of their teacher and by subject
Figure 4.5: Student scores separated by design experience of their teacher and by subject -continued
Figure 4.6: Student scores separated by method used in class
Figure 4.7: Student scores separated by the method used in class and by subject
Figure 4.7: Student scores separated by the method used in class and by subject -continued
Interestingly, the area where the school is situated also appears to have an influence on the learning environment. Students from schools from the 30 largest cities in the Netherlands score significantly lower on three of the WCQ scales than students from schools in more rural areas. Teachers in urban areas show stronger regulation \((F(1, 1557) = 6.75; p < 0.01; \omega^2 = 0.004)\) and a teaching emphasis more towards fundamental science \((F(1, 1557) = 10.86; p < 0.01; \omega^2 = 0.005)\).

### 4.6 Conclusion and Discussion

A questionnaire to measure context-based aspects of a learning environment has been constructed successfully. The separate context-based constructs as well as a general CBLE construct as derived from literature were found to be coherent by analysing the data obtained.

Dutch Chemistry students score their learning environment more context-based than biology, physics and ASMaT students. This advance in CBLE in chemistry as opposed to physics might be due to the introduction chemistry as a general subject in the curriculum in the 1980’s and the emphasis that was placed on student experiments (Hondebrink, 1987). Since chemistry then had to be taught to students who might not be interested in the subject as such, methods such as ‘chemistry and society’ and ‘chemistry in a 1000 questions’ were constructed.

For Dutch high school biology, humans and their environment are intrinsically suited to provide meaning to biological knowledge. Methods available to teachers often use these contexts to present the biological concepts. This might explain the high scores on the CBLE scale context and transfer. The high score on the regulation scale cannot be explained as easily. More research into the methods used in high school biology classes is necessary to explore why biology students experience more responsibility for their own learning.

The high score for the context and transfer scale for physics might be a direct result from the initiatives of PLON in the eighties (Hooymayers, 1986). Physics is known for its traditional teaching (Lyons, 2006), which is visible still in the WCQ scores (regulation, emphasis).

ASMaT is quite similar to physics by looking at the student WCQ scores.
However, the teachers do not agree with their students. The purpose of the subject was to deepen and broaden the scientific knowledge of students by immersing them in a context. The teachers might have taken the latter part of the training in the purpose of ASMaT as a point of reference, while the students focus on the current teaching: the deepening of scientific knowledge in a traditional manner. An emphasis more on the content rather than the context can thus be expected, explaining the likeness to physics. A distinguishing characteristic for this new subject is the tendency in the materials to involve group work and role-play as student learning activities. This would explain the high score on the regulation scale. Also the fact that ASMaT does not have a national exam might account for the more shared regulation found for ASMaT.

Teachers do not have different WCQ scores when they have design experience. Their students however do; students from teachers with design experience score significantly higher on all WCQ scales. The highest score are from students whose teachers are involved in designing standard materials and student experiments. These teachers might feel more confident about their teaching, and are thus able to create a CBLE. Context-based design experience influences the CBLE scores but less than ordinary material design. An explanation might be found in that the teachers are more aware of what context-based education entails and are more strict in trying to make it work. Another explanation might be that they do not agree with context-based education since they know what it entails and are acting accordingly. More research into the details of the context-based design experience is necessary to uncover what makes this difference occur.

An explanation for the result that teachers from urban areas use a stronger regulation teaching strategy and a more fundamental science teaching emphasis might be found in the different school climate that is found in cities. The students are generally more unruly, causing teachers to respond accordingly (Artiles, 1996).

Our research indicates that teachers strongly determine how context-based a learning environment is, but mainly by their choice of teaching material. It is apparent that the use of mixed materials (context-based materials in combination with a standard textbook) in teaching is key to achieving a CBLE. A reason for this is probably that only context-based materials provide the students with too much uncertainty about what they
actually have to learn. When they can rely on a book for the background scientific knowledge they can experiment more freely in the context-based student activities. This combination is the key to the success of Salters’ chemistry in the UK (Bennett, Gräsel, Parchmann, & Waddington, 2005; Bennett & Lubben, 2006) and is in their view essential to the context-based approach. Curriculum materials design for context-based education should consider this carefully, since it appears to be a key factor in the success of context-based education.

The instrument could be useful in future studies into CBLE’s in other countries. Comparative studies can be made using this instrument in combination with interviews and other research methods into the differences in teaching science subjects in different cultures. The subject specific findings could be the starting point of future research to uncover how the different science subjects could attain a CBLE. Also changes in CBLE in science classrooms could be monitored, should the Dutch Government instate the context-based curricula that have been constructed and tested.

4.7 Acknowledgement

The authors like to thank J.A.M. Voorbraak for his work in approaching schools and teachers to fill in the questionnaires and the digitalising of the data.
Chapter 5

An analysis of teaching competence in science teachers involved in the design of context-based curriculum materials


Abstract

The committees for the current Dutch context-based innovation in secondary science education employed teachers to design context-based curriculum materials. A study on the learning of science teachers in design teams for context-based curriculum materials is presented in this paper. In a correlation study, teachers with (n=25 and 840 students) and without (n=8 and 184 students) context-based curriculum material design experience were compared on context-based competence. Context-based competence comprises context handling, regulation, emphasis, design, and school innovation. Context-based teaching competence was mapped using both qualitative and quantitative research methods in a composite instrument.
Due to the differences in design team set-up for different science subjects, teachers with design experience from different science subjects were also compared on their context-based competence. It was found that teachers with design experience showed more context-based competence than their non-designing colleagues. Furthermore, teachers designing for biology showed more context-based competence than their peers from other science subjects.

5.1 Introduction

A trend in high school chemistry education in many countries is to switch to a context-based approach, due to the falling number of students enrolling in scientific further education (Bennett et al., 2007). It is believed that context-based education motivates students more for the subject, thus leading to a larger number of students continuing in scientific further education (Gilbert, 2006).

Science teachers have been involved in the design of curriculum materials in the context-based innovation in the science subjects in the UK, Germany, and the Netherlands. The reasons for this involvement are the expectation that teachers will be more willing to accept the innovation when they have been a part of it (Fullan, 1994) and to make the curriculum materials well-suited to classroom practice (Bennett & Lubben, 2006).

This paper centres on the question: what have science teachers who were involved in the design of context-based curriculum materials learned from that experience?

The majority of publications on context-based science education seem to concern high-school chemistry. In this study he focus is on the science subjects biology, chemistry, physics and advanced science, mathematics, and technology (ASMaT), since the Dutch curriculum innovations for these subjects have jointly chosen to use a context-based approach. In the remainder of this paper the term science is used to refer to these four high school science subjects.

In a review of research on context-based education Bennett et al. (2007) define this approach as:

“Context-based approaches are approaches adopted in science teaching where contexts and applications of science are used as
the starting point for the development of scientific ideas. This contrasts with more traditional approaches that cover scientific ideas first, before looking at applications” (p. 348).

An important accompanying element of context-based education described by Gilbert (2006) and by Parchmann et al. (2006) is active learning. This requires students to have a sense of ownership of the subject and to be responsible for their own learning. The combination of active learning and the use of contexts is consistent with the constructivist view of learning underlying context-based education (Gilbert, 2006).

In a previous study a context-based science education has been defined as an approach in which contexts that are meaningful to the student are used as the starting point for the learning of scientific concepts, students are responsible for their own learning (active learning) in an environment that can be organised by them and their teacher to their needs, interacting with other science subjects or outside-school organisations where appropriate (De Putter-Smits et al., in pressb). Teachers should be able to create a learning environment that contains these elements of context-based education. In the following paragraphs such teacher competence in context-based education is described.

Context handling In context-based education, teachers can be confronted with materials that contain contexts they are unfamiliar with. Hence, they are required to be capable to familiarise themselves with any context expressed in curriculum material and to be able to present and clarify it to the students. The context is to be used as a starting point for learning scientific concepts on a need-to-know basis (Parchmann et al., 2006). This differs from traditional education where the concepts are of foremost importance and are usually explained first before examples and applications are discussed. The required teacher attitude towards contexts is phrased by Gilbert (2006) as: “[. . . ], the teacher needs to bring together the socially accepted attributes of a context and the attributes of a context as far as these are recognised from the perspective of the students” (p. 965). Teachers have to be aware of the need for concept transfer (to other contexts) (Van Oers, 1998). The context should cause a need for students to explore and learn concepts and to apply them to different situations. This teacher competence (context, concept, and re-contextualising) is referred to as context handling.
**Regulation**  In traditional science education the responsibility for learning rests mainly with the teacher described by Vermunt and Verloop (1999) as ‘strong teacher regulation’. Friction between student learning and teacher activities can for instance arise when loose regulative student materials are taught by teachers only experienced in strong regulative teaching activities (Vermunt & Verloop, 1999). In context-based education the responsibility for learning is shared by teacher and learner, requiring teachers to change their teaching activities into shared or loose control strategies. Teachers should be competent in handling the kind of activities required, i.e. to guide rather than control the learning process of the students. This teacher competence is referred to as regulation.

**Emphasis**  Using contexts as a starting point for learning corresponds to a different teaching emphasis as compared to traditional science education (Gilbert, 2006). Emphasis has been defined thus by Roberts (1982):

> “A curriculum emphasis in science education is a coherent set of messages to the student about science [. . .]. Such messages constitute objectives which go beyond learning the facts, principles, laws, and theories of the subject matter itself -objectives which provide answers to the student question: “Why am I learning this?”” (p. 245).

Generalising the emphases described by Van Driel et al. (2005) from chemistry to science, three different emphases can be identified:

> “a fundamental science (FS) emphasis where theoretical notions are taught first because it is believed that such notions later on can provide a basis for understanding the natural world, and are needed for the students future education; a knowledge development in science (KDS) emphasis where students should learn how knowledge in science is developed in socio-historical contexts, so that they learn to see science as a culturally determined system of knowledge, which is constantly developing; and a science, technology and society (STS) emphasis where students should learn to communicate and make decisions about social issues involving scientific aspects.” (De Putter-Smits et al., 2011, p. 36)

An STS or KDS teaching emphasis is a competence referred to as emphasis.
**Design**  
Seen from a constructivist perspective, the available context-based materials are not immediately suited to every classroom or to the needs of the students and teachers. Besides this, the more active role for the student embedded in the context-based curriculum material requires activities such as experiments that put a demand on time tables. The necessity for the teachers to redesign the material to the schools’ facilities arises, since it is unlikely that all schools have the opportunity to meet the exact requirements of the context-based materials e.g. computer and experimentation facilities.

Student regulated learning can lead to unpredictable learning demands, causing the teachers to redesign education on the spot, including new lesson plans, curriculum materials, experiments and so on. Teachers are therefore expected to (re-)‘design’ the context-based material. Hence, it is expected that the educational *design* teacher competence is in demand in context-based education and might be new to traditional teachers.

**School innovation**  
Teachers have to cooperate with colleagues of their subject field and even possibly across science subjects to implement the context-based approach, in order to create coherence in the science curricula. An innovation cannot succeed if it is only supported by isolated teachers (Fullan, 1994). The Dutch innovation committees expect teachers to be representatives of the innovation in their schools (Boersma et al., 2007; Steering Committee Advanced Science, Mathematics and Technology, 2008). An increased belief and wish to collaborate within schools is observed among teachers involved in developing curriculum materials for ‘Chemie im Kontext’ (ChiK) in a study into the learning effects. These teachers are also likely to be involved in collaborative relationships in their own schools (Gräsel et al., 2006). This teacher competence is referred to as *school innovation*.

The five teachers competences identified as important for teaching context-based education have been described. They are: context-handling, regulation, emphasis, design, and school innovation.

**5.1.1 Learning through the design of materials**

There are several empirical studies in which teachers were involved in the design of study materials (cf. Linn, Clark, & Slotta, 2003; Hoogveld, Paas, & Jochems, 2005). However, most focus on the quality of the material and/or the results of student learning. Only few studies have been concerned
Design of curriculum materials is described as an important activity for teacher learning (Deketelaere & Kelchtermans, 1996; Borko, Jacobs, & Koellner, 2010). The reasoning behind this is that teacher learning benefits from the proximity of the design of curriculum materials to the actual teaching practice, resulting in a 'sense of ownership' (Borko et al., 2010). In combination with the actual teaching of the curriculum materials made the learning is expected to be more profound (Deketelaere & Kelchtermans, 1996). Deketelaere and Kelchtermans (1996) go on to conclude that the combination of teachers and university experts in curriculum design teams leads to not only better materials, but also to more profound teacher learning.

Changes in teaching practice, that were the result of science teachers being involved in the design of context-based curriculum material, were reported in three cases. Parchmann et al. (2006) reported a change in the context-handling competence of chemistry teachers; Mikelskis-Seifert et al. (2007) reported a change in the regulation competence of physics teachers; Gräsel et al. (2006) reported a change in the school innovation competence of chemistry teachers. A change in teacher competence in creating a context-based learning environment can thus be expected of teachers working in context-based curriculum design teams.

5.1.2 Background to this study: the Dutch context-based innovation

The Dutch Ministry of Education, Culture and Science has instituted committees for the high school subjects biology, chemistry, physics, and advanced science mathematics and technology (ASMaT) with the assignment to develop new science curricula. The new curricula should cover modern science, relieve the current overloaded curricula and interest more students in choosing science in further studies (cf. Kuiper et al., 2009a). These science curricula were meant for years 10 and 11 of senior general secondary education and for years 10-12 of pre-university education. The subject ASMaT differs from the other science subjects in that it is a newly created school subject for which, up to then, no curriculum or learning goal had been designed (Steering Committee Advanced Science, Mathematics and Technology, 2008). All committees decide to use a form of context-based education (Boersma et al., 2006) to counter the falling popularity of science
subjects among students, also visible in the Netherlands (A. M. W. Bulte et al., 2000).

The innovation committees were committed not just to presenting a ‘list of concepts’ to the Ministry of Education, Culture and Science, but to providing a tried and working curriculum (cf Driessen & Meinema, 2003). To this end, they enlisted teachers to develop aspects of the context-based curriculum, i.e. curriculum modules, textbooks, workbooks, worksheets for experiments in cooperation with experts on the pedagogy of science. Each of the novel science curricula was tested in schools throughout the Netherlands for three years, including an adapted national final exam.

However, all committees differed in their explanation of context-based education, and hence in the guide-lines presented to the design teams. They also differed in the set-up and organisation of the respective curriculum design teams and in the available funding (Steering Committee Advanced Science, Mathematics and Technology, 2008; Commissie Vernieuwing Natuurkunde Onderwijs HAVO/VWO [Innovation committee high school physics education], 2006; Driessen & Meinema, 2003; Boersma et al., 2007). The differences between the teams from different science subjects will be discussed in some detail, since this study concerns the learning of teachers in the various curriculum design teams. An overview of the characteristics of the different design teams is provided in Table 5.1.

The biology innovation committee chose a strategy where one or more teachers per school would design curriculum modules and try them in class and improve the module where necessary. In all, seven schools were selected where teachers made the curriculum modules, sharing them with the other schools. In practice this meant in some schools one teacher working on his own, testing his own material; in other schools there were more teachers involved in the design and try-out of the curriculum modules. The schools were funded to provide the designing teacher with time for the curriculum design activity.

The chemistry innovation committee’s strategy was to ‘let all flowers blossom’. Besides the official start document (Driessen & Meinema, 2003) no other guidelines were provided. Teachers, experts and known curriculum designers were asked to make curriculum materials. Little funds were available for this endeavour from the innovation committee, however an in-
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dustrial lobby also involved itself, providing some funds for teachers and educational experts to design curriculum materials in cooperation with experts from industry on modern applications of chemistry. The material designed for the context-based chemistry innovation varies in the interpretation of context-based education and in the concepts covered in each curriculum module. The committee organised the completed modules into four major learning continuity pathways (roughly corresponding to the different interpretations of context-based education) to be able to test the curriculum in a national exam.

The physics innovation committee appointed volunteering teachers and combined them with experts to make curriculum modules on certain concepts. The teams consisted of one teacher to design the module, assisted by one or more teachers to comment and try the module, an expert on the pedagogy of physics and a content expert. The designer-teacher was provided with exemplary curriculum material from other countries and a design model (the generic analysis, design, development, implementation and evaluation model often referred to as ADDIE). As it turned out, the quality and progress of the work varied, inducing the committee to change the approach. The most promising designer-teachers were asked to finish all the curriculum materials made so far with the help of experts on the pedagogy of physics (approximately eight teams of two people). An editor was hired to create coherence in the series of modules that would cover the curriculum. The curriculum modules were tested in different schools from those where the designer-teachers worked.

ASMaT was a new subject, for which no materials were available. This gave the teachers even more freedom in designing their own curriculum and materials, drawing even stronger on the competence of ‘design’. The ASMaT committee had relatively large funds available for their endeavour to design a curriculum, having corresponding materials made and having the curriculum modules tried in classrooms. Schools were invited to find a partner-school to make an ASMaT module in return for funding. The schools were required to submit a proposal along strict guidelines, describing details on the context chosen, the concepts to be covered and the project planning. Per school two teachers were involved and the committee provided each team with a coach and access to experts on the context chosen. The curriculum modules were tested in a third school before they were finally submitted to the committee, who then certified the module, or altered it
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using a professional editor as it saw fit.

Table 5.1: Overview of design team characteristics for the different subjects

<table>
<thead>
<tr>
<th></th>
<th>ASMaT</th>
<th>Biology</th>
<th>Chemistry</th>
<th>Physics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Start</strong></td>
<td>2006</td>
<td>2006</td>
<td>2003</td>
<td>2006</td>
</tr>
<tr>
<td><strong>Design Team</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-finance</td>
<td>available</td>
<td>available</td>
<td>little - none</td>
<td>little - none</td>
</tr>
<tr>
<td>-no of teachers</td>
<td>minimum of 4</td>
<td>1 (one of the teams has more)</td>
<td>varies 1-6</td>
<td>1-3</td>
</tr>
<tr>
<td>-from no of schools</td>
<td>2</td>
<td>1</td>
<td>1 to 5</td>
<td>up to 3</td>
</tr>
<tr>
<td>-experts</td>
<td>available</td>
<td>available to 2 teams</td>
<td>0 to 6</td>
<td>1 to 5</td>
</tr>
<tr>
<td>-no of teams</td>
<td>&gt; 50</td>
<td>14 (from 7 different schools)</td>
<td>50-100</td>
<td>10</td>
</tr>
<tr>
<td><strong>Instructions</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-Design process</td>
<td>available</td>
<td>none</td>
<td>none</td>
<td>model</td>
</tr>
<tr>
<td>-Context-based education</td>
<td>not strict</td>
<td>none</td>
<td>not strict</td>
<td>not strict</td>
</tr>
<tr>
<td><strong>Materials</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-Test method</td>
<td>other school</td>
<td>own school</td>
<td>varies</td>
<td>other school</td>
</tr>
<tr>
<td>-Controlled by committee</td>
<td>certificate</td>
<td>partly</td>
<td>partly</td>
<td>yes</td>
</tr>
<tr>
<td>-Published by committee</td>
<td>website</td>
<td>DVD and website</td>
<td>website</td>
<td>DVD and website</td>
</tr>
</tbody>
</table>

In this research active science teachers that have designed curriculum materials for one of the four Dutch innovation committees were studied. The research questions addressed in this paper were:

1. What are the context-based teaching competencies of science teachers who have worked in design teams for context-based curriculum materials and can these competencies be attributed to the design team work?

2. What are the differences in context-based competence of science teachers who designed for different science subjects?

3. What other (informal) learning do teachers who have worked in context-based curriculum design teams experience?
5.2 Research Design

Science teachers from ASMaT, biology, chemistry and physics were studied on their competence in context-based education to answer the research questions. In the remainder of this paper science teachers with curriculum design experience for the context-based innovation are referred to as designers, as opposed to non-designers or teachers for those who do not have design experience.

The study is in retrospect since most curriculum design teams have finished their task. Therefore, designers were compared to teachers to evaluate whether there are differences between the two groups. The designers and non-designers were asked to attribute their context-based competence.

Another comparison made, was whether there are differences in context-based teaching competence in designers connected to the subject they designed for.

5.2.1 Participants

From the lists of authors of official (approved by the innovation committees) context-based curriculum materials, 50 teachers who were still teaching were approached by phone and email to join this study. Of these teachers, 25 accepted the invitation. From the network of the authors 50 science teachers without context-based curriculum material design experience were recruited to join the study. Here, 8 teachers accepted the invitation. Care was taken that all teachers form a group adequately representing ‘Dutch science teachers’ with respect to key variables such as experience, education and subject. No teachers for ASMaT were present in this sample, since ASMaT is a new subject. In Table 5.2 an overview of the participants is presented.

<table>
<thead>
<tr>
<th>Designers per subject they designed for</th>
<th>ASMaT</th>
<th>Biology</th>
<th>Chemistry</th>
<th>Physics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students from designers</td>
<td>243</td>
<td>177</td>
<td>214</td>
<td>206</td>
</tr>
<tr>
<td>Teachers per subject they teach</td>
<td>-</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Students from participating teachers</td>
<td>-</td>
<td>86</td>
<td>46</td>
<td>52</td>
</tr>
</tbody>
</table>

Table 5.2: Overview of the participants
5.2.2 Instrument

The instrument used to map the context-based competences of the designers and teachers included both qualitative and quantitative research methods. Since this composite instrument was to be used in a Dutch research setting, it was designed and tested in the Dutch language. The focus of the instrument was on the context-based learning environment the teachers were able to create, both on the cognitive and the behavioural dimension. The composite instrument provided data that were recalculated into a score for all the context-based competences as presented in the schematic in Figure 5.1. The components of the instruments and a sample calculation of a competence score are described below.

The reliability and validity of the composite instrument was established in a pilot-study (De Putter-Smits et al., 2009). A Cronbach’s alpha of 0.84 was obtained for the total context-based competence scale. The instruments’ power to discriminate between teachers with varying backgrounds (predictive validity) was also established in the pilot-study (De Putter-Smits et al., in pressb, chapter 2 in this thesis).

The WCQ-questionnaire consists of scales from international standard questionnaires such as the WIHIC (Dorman, 2003) and the CLES (Johnson & McClure, 2004). For the Dutch setting, the items were translated. The WCQ was used in a national study where its validity to measure the context-based learning environment was established (De Putter-Smits, Tacs, & Jochems, in press, chapter 4 in this thesis). The scale representing the competence of context-handling contained 17 items with a Cronbach’s alpha of 0.91. The scale representing the competence of regulation contained 13 items with a Cronbach’s alpha of 0.85. The scale representing the competence of emphasis contained 12 items with a Cronbach’s alpha of 0.83 (De Putter-Smits et al., in pressa).

The (originally Dutch) emphasis questionnaire developed by Van Driel
et al. (2005) was adapted to represent all science subjects. It was validated among 213 science teachers. Three scales (FS, KDS and STS) were confirmed with Cronbach’s alpha ranging from 0.73-0.90 (De Putter-Smits et al., 2011, chapter 3 in this thesis).

The semi-structured interview contained questions on the context-based competences. Answers to interview questions were assessed by two researchers independently using a codebook (Ryan & Bernard, 2000) and scored on a five-point Likert scale. Next, the scores are discussed until full agreement was obtained. For instance the answer to the question: *What does context-based education entail? -specifically on the context?* was given a five when all the elements of the context-handling competence (see theory section) were present and explained by the participant’s answer. Some interview questions required answers as a percentage, for instance: *Can you indicate on this scale what percentage of control lies with you as a teacher?*

To compensate for the difference in scales all scores were standardised before proceeding. The z-scores per competence were then combined into a score per competence and finally into a total score on the cognitive and on the behavioural dimension. An example of such a calculation for the context-handling competence on the cognitive level is: taking the average of the WCQ average z-score on the context-handling scale and the average z-score of the interview questions on context-handling (two questions). The composite instrument was validated in a pilot-study where a Cronbach’s alpha of 0.84 was obtained (De Putter-Smits et al., in pressb).

### 5.2.3 Analysis

All scores were calculated as indicated in the instrument section. To confirm the reliability of the instrument the Cronbach’s alpha of the items per cognitive and behavioural competency scale was computed. Next the participants’ background characteristics were analysed to ensure the designers and non-designers were comparable for the purpose of this study. Possible influencing background characteristics were identified by correlating them with the context-based competency scores.

To answer the first part of research question one, a t-test was performed between the scores of the designers and the scores of the teachers.
To answer the second part of research question one, the participants were asked to attribute their knowledge on context-based education, this being a retrospect study. The answers of the designers to the question: *How did you acquire your knowledge on context-based education?* were analysed. The answers were tallied into six categories, five pre-suggested ones (course or workshop, symposium organised by innovation committee, publication of the innovation committees, design team *work*, through a design team *member*) and one ‘other’. These attributions were correlated with the different context-based competence scores to obtain insight into which aspect(s) is most important for learning to teach context-based education, e.g. they attributed their learning to their teacher education, their teaching experience, their curriculum design experience etc.

The second research question was answered by comparing the scores from the designers per subject they designed for using a Mann-Whitney U test. Where appropriate, qualitative results are provided to illustrate quantitative results.

To answer the third research question all additional mentioned learning experiences, including implicit learning (Eraut, 2004), were analysed by coding the experiences, categorising the codes and identifying themes and relationships among the codes and categories (Miles & Huberman, 1994).

### 5.3 Results

#### 5.3.1 Participant analysis

The analysis showed that for biology five of the possible fourteen biology designers and six of the ten physics designers were part of this study. Compared to the number of designers for chemistry and ASMaT in the study (6 and 8 out of an estimated 50-100 designers) the designers for biology and physics in this study were more likely to represent the group of designers for their subject.

Not all designers teach the subject they designed curriculum material for. There were no teachers for the new curricular subject ASMaT in the study.

The 25 designers were compared to eight non-designers on their context-based education competences. To ensure the sub-samples were comparable the teachers’ background characteristics were analysed.
A t-test confirmed that the non-designers were significantly younger than the designers ($t(31) = -2.16, p < 0.05, r = 0.36$), although the effect size is medium. However, the differences in teaching experience and teaching qualification between the two groups were not significant. Teachers with more than five years of teaching experience are considered to have developed an expertise in teaching (Berliner, 2001) making the participants comparable in that respect.

A distinguishing characteristic of designers was holding a relevant additional job, such as designing study material for universities (10 out of 25) or teaching pedagogy of science to student teachers (11 out of 25). However, further analysis of the data revealed no significant influences of ‘additional jobs’ on the total context-based competency score.

A further analysis of possible influences was carried out, revealing no further indications of deviations in the sample.

5.3.2 Instrument analysis

All answers to competency questions were analysed and scored by two researchers working separately, reaching an agreement of 0.80 (Cohen’s kappa). Next the differing items were discussed until full agreement was obtained.

The competency scale scores were constructed as described in the instrument section out of the standardised score for each item. For each scale of the instrument the Cronbach’s alpha was calculated. The results on the instrument’s reliability are depicted in Table 5.3. The item rest correlations for the cognitive competency scales showed considerable overlap ($> 0.40$), which is expected since these scales together form one total context-based competency scale (De Putter-Smits et al., 2009). School innovation was an exception to this. This was expected since the school innovation competency was designed to measure interactions outside the classroom rather than those related to classroom practice (the other four) (De Putter-Smits et al., in pressb). The behavioural competency scales showed high correlations. This indicated that students could not (or were not able to) discriminate among the different teaching competencies within the general context-based competence, whereas the teachers and the researchers could. However, a multi-level analysis in the national study using this part of the composite instrument clearly indicated that the scales are separate, though related as shown in Figure 5.1 (De Putter-Smits et al., in pressa).

The reliability coefficient (Cronbach’s alpha) for the scale ‘total score’
Table 5.3: Context-based competency scales - reliability

<table>
<thead>
<tr>
<th>Scale</th>
<th>Cognitive</th>
<th>Behavioural</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of indicators k</td>
<td>Alpha</td>
</tr>
<tr>
<td>Context handling</td>
<td>9</td>
<td>0.84</td>
</tr>
<tr>
<td>Regulation</td>
<td>20</td>
<td>0.74</td>
</tr>
<tr>
<td>Emphasis</td>
<td>41</td>
<td>0.58</td>
</tr>
<tr>
<td>Design</td>
<td>2</td>
<td>0.68</td>
</tr>
<tr>
<td>School innovation</td>
<td>4</td>
<td>0.50</td>
</tr>
<tr>
<td>Total score</td>
<td>76</td>
<td>0.71</td>
</tr>
</tbody>
</table>

was found to be 0.78.

5.3.3 Context-based competency scores and context-based design experience

The results on the first part of research question one, whether context-based curriculum design experience is an underlying factor of context-based teaching competence are presented below.

The means and standard deviation of the context-based competency scores for all teachers were computed and are shown in Table 5.4.

A t-test (one-tailed) indicated a significant positive difference between designers and non-designers on the total cognitive competency score ($t(31) = 1.95; r = 0.39$). For the separate cognitive scales a positive relation of design team experience with ‘context handling’ and ‘design’ was found ($t(31) = 2.60; r = 0.52$ and $2.42; r = 0.45$ respectively). These effect sizes are medium to large (> 0.30 is medium; > 0.50 is large Cohen (1992)). For the behavioural scales no significant result was found.

5.3.4 Knowledge of context-based education

The answer to the second part of the first research question on where the designers attributed their knowledge on context-based education to is described next.

A qualitative analysis of the category other revealed two extra categories: a person in the teachers’ direct environment such as a colleague or professional friend and internet documentation and books.
Table 5.4: Context-based competency scores of designers and non-designers and significant differences between the two groups

<table>
<thead>
<tr>
<th>Scale</th>
<th>Cognitive</th>
<th>Behavioural</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Designers</td>
<td>Non-designers</td>
</tr>
<tr>
<td>Context handling</td>
<td>0.17**</td>
<td>-0.58</td>
</tr>
<tr>
<td>Regulation</td>
<td>0.03</td>
<td>-0.06</td>
</tr>
<tr>
<td>Emphasis</td>
<td>0.07</td>
<td>-0.17</td>
</tr>
<tr>
<td>Design</td>
<td>0.19**</td>
<td>-0.60</td>
</tr>
<tr>
<td>School innovation</td>
<td>-0.10</td>
<td>-0.18</td>
</tr>
<tr>
<td>Total score</td>
<td>0.07*</td>
<td>-0.32</td>
</tr>
</tbody>
</table>

n 25 8 25 8

*Significant with $p < 0.05$

**Significant with $p < 0.01$

Of the five pre-suggested sources and the two other sources of knowledge on context-based education named by the designers design team work and through a design team member correlated significantly with the context-based competence scores. These are shown in Table 5.5. None of the other categories correlated significantly with the context-based competencies, official meetings or publications of the innovation committees included.

From the analyses of the interviews it was apparent that many designers had followed one or more official symposia organised by the respective innovation committees. Although they all indicated they had been to these symposia, they also almost all indicated that their knowledge on context-based education was not influenced by them. According to the designers, making the context-based materials, discussing context-based education with peers and experts during this process and other occasions, as well as trying them in class gave them the knowledge they have on context-based education. Or as they put it: “made it clear how context-based education actually works” (quote from semi-structured interview).
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Table 5.5: Correlating sources for knowledge on context-based education with context-based teaching competency scores for designers (n=25)

<table>
<thead>
<tr>
<th>Scale</th>
<th>Design team work</th>
<th>Through design team member</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cognitive</td>
<td>Behavioural</td>
</tr>
<tr>
<td>Context handling</td>
<td>0.50*</td>
<td></td>
</tr>
<tr>
<td>Regulation</td>
<td>0.47*</td>
<td></td>
</tr>
<tr>
<td>Emphasis</td>
<td>0.41*</td>
<td>0.44*</td>
</tr>
<tr>
<td>Design</td>
<td></td>
<td></td>
</tr>
<tr>
<td>School innovation</td>
<td>0.43*</td>
<td></td>
</tr>
<tr>
<td>Total score</td>
<td>0.61**</td>
<td></td>
</tr>
</tbody>
</table>

*Correlation is significant at the 0.05 level (two-tailed)
**Correlation is significant at the 0.01 level (two-tailed)

5.3.5 Context-based competency scores and design experience per science subject designed for

The results to the second research question on the differences in teacher competence between science subjects teachers have designed for are described below.

The means and standard deviations of the context-based competence scores per subject designed for are provided in Table 5.6. A Mann-Whitney U test revealed significant positive differences on the cognitive context-based competence scores for designers for biology and chemistry. Negative significant differences were found for designers for ASMaT. Other U-values were not significant.

During the interview four of the designers admitted they had only joined the ASMaT design team because the school they worked for required it of them. When the project was finished they resumed their usual teaching practice, where, according to them, the ASMaT experience had no relevance. When asked whether they did not feel inclined to look at the innovations that are taking place in their usual teaching field, the answers of the designers varied from: “Currently I work with children with autism spectrum disorder. Context-education is not suitable to their needs” to “I am a very good teacher, my students tell me and I believe the classical way of teaching suits me and them best” or “I am interested but cautious. I am
An analysis of teaching competence

Table 5.6: Context-based competency scores per science subject designed for and significant differences comparing one subject to all others

<table>
<thead>
<tr>
<th>Scale</th>
<th>ASMaT</th>
<th>Biology</th>
<th>Chemistry</th>
<th>Physics</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>8</td>
<td>5</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Cognitive</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Context handling</td>
<td>-0.36*</td>
<td>0.87</td>
<td>0.80*</td>
<td>0.27</td>
</tr>
<tr>
<td>Regulation</td>
<td>-0.50**</td>
<td>0.69</td>
<td>0.55*</td>
<td>0.35</td>
</tr>
<tr>
<td>Emphasis</td>
<td>-0.47</td>
<td>0.97</td>
<td>0.26</td>
<td>0.37</td>
</tr>
<tr>
<td>Design</td>
<td>-0.40*</td>
<td>0.77</td>
<td>0.92*</td>
<td>0.50</td>
</tr>
<tr>
<td>School innovation</td>
<td>-0.21</td>
<td>0.68</td>
<td>0.29</td>
<td>1.06</td>
</tr>
<tr>
<td>Total score</td>
<td>-0.39**</td>
<td>0.53</td>
<td>0.57**</td>
<td>0.12</td>
</tr>
<tr>
<td>Behavioural</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Context handling</td>
<td>-0.19</td>
<td>1.06</td>
<td>0.41</td>
<td>1.13</td>
</tr>
<tr>
<td>Regulation</td>
<td>-0.48</td>
<td>0.41</td>
<td>0.31*</td>
<td>0.55</td>
</tr>
<tr>
<td>Emphasis</td>
<td>-0.31</td>
<td>0.83</td>
<td>0.51</td>
<td>0.99</td>
</tr>
<tr>
<td>Total score</td>
<td>-0.33</td>
<td>0.66</td>
<td>0.41</td>
<td>0.84</td>
</tr>
</tbody>
</table>

*Significant with $p < 0.05$

**Significant with $p < 0.01$

working on my higher teaching qualification, I am the school’s IT man, so I won’t be a frontrunner on this one”, and “In our school classical teaching is advertised both to new teachers such as myself as to the outside world: we are an old-fashioned good school” (teacher remarks during semi-structured interview).

5.3.6 Other teacher learning in design teams

During the semi-structured interview all designers were asked what other learning experience they had during the design process that had not been covered by earlier questions. From the qualitative analysis of the answers four categories of learning were identified: elements of context-based education -not previously described in the theory section, the technical part of the writing process, learning about the context-based innovation on a macro
level, and learning about personal abilities.

Eight teachers included other elements of context-based education than was defined specifically in the theory section above. One teacher added to the context definition by stating that: “The purpose of experiments has changed from explanation of the theory to the practical purpose of the theory”. Another teacher depreciated the context element by stating that: “Each paragraph now starts with a context before going into theory”.

On the regulative implications of context-based education six teachers added more specifics. Two teachers added learning by inquiry as specific to context-based education, two teachers added that the test methods are different and more diverse in context-based education, one teacher added that students should learn by using the generic ADDIE design model (analysis, design, development, implement, evaluation, used for education among others by (Plomp, 1982)) and one teacher referred to context-based education as girl oriented learning.

Examples of learning about the technical part of the writing process reported by the teachers were: “Working with a predefined structure is important”, “Writing means deleting text”, “I learned how to handle computer viruses”, “When working in a team make solid agreements and keep each other to these agreements”, and “Writing takes up a lot of time”.

Examples of learning on the innovation on a macro level were: “The method the committee uses to develop the new curriculum does not help nationwide integration” and “My frame of reference for the purposes of my science subject outside the classroom had broadened”.

Examples of a personal ability learning experience were: “I have discovered my own creativity; what I am good at as a writer” and “Personally, I now have more appreciation for material colleagues have made”.

5.4 Conclusions and Discussion

The designers and non-designers in the sample were found to be comparable on the average years of teaching experience and the lack of influences of variables such as ‘having an additional job in the pedagogy of science’. From the reliability data (see Table 5.3) it could be concluded that the
instrument performs well.

**RQ1** From the results it could be concluded that the context-based teaching competences ‘context handling’ and ‘design’ are significantly more developed in designers than in non-designers. For the other context-based competences no significant differences between designers and non-designers were found.

Higher context-based teaching competence was found for designers who attributed their knowledge of context-based education to having worked in a context-based design team. It could also be concluded that context-based teaching competence in context-based education is not related to having read publications from the innovation committees or having attended official symposia (organised by the innovation committees). The conclusion on the latter is not surprising since it is known that single-day workshops are ineffective in changing teaching practice (cf Borko & Putnam, 1996).

Combining the result for research question one, the process of designing context-based teaching materials appears to be a powerful source to develop the context-based teaching competencies. This result concurs with the conclusion Coenders draws in his case-study of teachers’ professional growth during the development of context-based chemistry materials: “involvement in the development process of innovative material is crucial for teacher learning” (Coenders, 2010, p. 150).

While various competencies were found to correlate significantly with design experience on a cognitive level this was not the case on the behavioural level, which is not unusual in learning environment research. It is suggested that students might be unable to discriminate between the different teaching competencies. Though there is a significant correlation of design team membership with classroom context-based competencies on a cognitive level, and in the teachers self-perception of classroom practice, this might not be recognised by their students and thus not appear on the behavioural level with the instrument (student opinion only). Another explanation might be that the designers have not yet learned enough for the effect to be visible in their classroom. In a German study physics teachers were found to have changed their teaching practice towards context-based education after three years of designing and teaching context-based curriculum materials (Mikelskis-Seifert et al., 2007).
RQ2  It could be concluded from the results on the second research question, that the subject the teacher has designed for is related to the level of context-based teaching competence. This result could be explained by the nature of the science subject itself, by the set-up of the various design teams or by the sample of designers in this study.

*Biology* designers showed more cognitive context-based competence than the other designers, with context handling, regulation and design as underlying competencies. On the behavioural competency scales biology designers showed more competence on regulation. Explanations could be sought in the more contextual nature of biology (in the Netherlands) as a subject, but that would not explain why the regulation and design competence were also significantly higher.

Another explanation might be found in the set-up of the biology design teams. This group of designers has the most experience in designing material since they needed to design an entire (three-year) curriculum for their own classrooms, preparing their students for context-based national exams. They were also given time (i.e. money) to work on materials for this entire new curriculum. In general, the active learning, i.e. the design of context-based curriculum materials and teaching using these materials, and content related nature, i.e. teaching biology to their own students in a different way, of the work the biology designers have undertaken, are known to be vital ingredients for successful teacher professional development (cf. Borko et al., 2010). This could explain why the biology designers in this study score higher on context-based competence.

Half of all context-based biology designers in the Netherlands participated in this research. This means our results were representative for the biology designers in the current innovation. This strongly indicated that for the biology innovation the cognitive teaching competencies context handling, regulation and design and the behavioural teaching competency regulation were effectively strengthened by the teachers’ design experience.

*ASMaT*-designers scored significantly lower than the other designers on context-based competence. The goal of ASMaT was to go scientifically deeper into a subject of interest to the student, for instance how to construct a zero-energy house. This may require a learning of scientific concepts that goes beyond the expertise of the teacher, which in turn causes them to resort to traditional teaching.

Another explanation could be that not all teachers volunteered for designing
curriculum modules. This could lead to a situation where, as soon as the task was over, they resumed business as usual. Another possible explanation is the fact that five of the eight designers in this sample do not teach using their own context-based materials or any other context-based material. This means that as a group they have not had the same opportunities as other designers to practice context-based competence in class. The lack of opportunity to use the innovative material in their classrooms hinders their professional development towards context-based education, as is suggested by the work of Coenders (2010). It certainly hinders them to show their context-based competence. There have been more than one hundred ASMaT curriculum designers. The results for the eight designers in our study might not be representative for all ASMaT designers.

Chemistry designers had a significantly higher cognitive emphasis teaching competence compared to the other designers. This could be explained by the strong focus on KDS teaching emphasis in the Netherlands that was advocated by both the current and the previous innovation committee. From the 1980’s onward an innovation in high school chemistry is ongoing that introduced experiments and explanations for phenomena into the chemistry curriculum (Hondebrink, 1987). Compared to the other designers no other significant differences in context-based competencies were found, indicating that designing chemistry materials itself does not lead to increased context-based competence. The set-up for the Dutch chemistry design teams varied widely, making it difficult to generalise the results. Also there have been more than one hundred chemistry curriculum designers. The results for the six designers in our study might not be representative for all chemistry designers.

Designers who made material for physics did not show any significant differences from the other designers. Their context-based competency scores were low compared to chemistry and biology designers. In the Netherlands, a prior innovation has introduced contexts to learning physics (Eijkelhof et al., 1986). Although teaching methods now include the application of physics concepts, the teaching is generally traditional. This could explain the result found for physics designers. The design teams did focus on a single writer, however the try-out of the materials was not usually in the designers own classroom, hindering the before mentioned active learning, which might explain the result.
The designers in this study were representative of the physics designers in the sense that six of the ten main designers participated. It could be concluded that designing context-based materials for physics did not lead to context-based teaching competence. This is in line with the conclusions in the evaluation study of Kuiper et al. (2009c) that the innovative material for physics is not recognised by teachers as representing a new concept of education. In popular debates between pro-innovation and contra-innovation physics teachers and committee members it was often stressed that no ‘state directed pedagogy’ should be enforced (cf Van Weert & Pieters, 2009). The apparent non-professionalising of physics designers towards context-based education could thus be explained.

Another factor influencing designers in general could be that for many the step to switch to context-based teaching is blocked by their fear of not preparing their students adequately for the national exams (George & Lubben, 2002). Only the schools involved in the context-based national exam trial could request context-based national exams.

RQ3 Other learning included possible additions to context-based competences. Learning by inquiry and the use of a specific strategy such as the ADDIE-model could be categorised under the regulation competency, since this kind of learning activity requires students to have more control over their learning process (Bateman, 1990).

Different test methods are mentioned in professional publications for ChiK in Germany, where teachers are handed tools to change test methods when teaching Chemie im Kontext (Nentwig, Christiansen, & Steinhoff, 2004). Context-based testing methods could therefore be added to the competence of regulation.

The remark that context-based education is more suitable for girls has been commented on in literature by Bennett et al. (2007) who concluded in their review of 17 experimental studies that both boys and girls showed a more positive attitude towards science when studying the subject with a context-based approach. Girl-oriented will therefore not be added as a possible context-based teaching competence.

The other learning reported by the designers was mainly related to the work of the team. Two other categories of informal learning were identified: acquiring a view on macro level on the innovation and personal abilities.
General impact and future research  From this research it could be concluded that teachers working in design teams for context-based material who are using these (and other) materials in their classroom showed increased context-based teaching competencies. The design strategy the biology innovation committee used seemed the most fruitful for acquiring context-based teaching competence when designing curriculum materials, since it incorporated some of the succes factors in teacher professional development (Borko et al., 2010). This study also confirmed the study by Coenders (2010) that teachers who do not use context-based material after designing context-based material do not show context-based competence. Designing curriculum materials was shown to lead to professionalisation of teachers towards context-based education. Future research could be directed at strategies for setting up design teams, such that they are in harmony with the subject to be designed for. The necessity for setting up such teams arises when the context-based curricula of the different science subjects are implemented nationwide in the Netherlands from 2013 onwards.
Chapter 6

Design of a professional development programme for context-based teaching competence through the design of instructional materials

Article submitted.

abstract

Teachers need to acquire specific competences to teach context-based science subjects. A literature study and an empirical study were performed identifying factors that promote teacher professional development towards context-based education. From literature designing curriculum materials was found an important means of teacher professional development. Therefore, an empirical study was conducted among teachers (n=25) that were experienced in designing context-based curriculum materials. Factors that promote teacher professional development found in the studies were used to design a detailed teacher professional development programme aimed at acquiring context-based teaching competence. Considerations and limitations of the programme presented were discussed.
6.1 Introduction

In several countries secondary chemistry education has adopted a context-based approach to teaching. In the United States examples of context-based chemistry are *Chemistry in context* and *Chemistry in the community* (Schwartz, 2006) and in the UK *Salters’ Advanced Chemistry* is most prominent (Bennett & Lubben, 2006). In the UK, Germany, and in the Netherlands the context-based approach is also introduced to other science subjects, such as advanced science mathematics and technology (ASMaT), biology, and physics (Pilot & Bulte, 2006a).

Teachers play a crucial role in innovations as they have to teach the innovated subject in their classrooms (Fullan, 1994). In context-based innovations the importance of teachers was recognised and their help was sought in developing curriculum materials, e.g. textbooks, workbooks, and worksheets for experiments, based on the context-based approach (Bennett & Lubben, 2006). The idea behind the involvement of teachers in designing curriculum materials is two-fold. First, the instructional materials for students and teachers could thus be attuned to teaching practice. Second, it is expected that the innovation will gain support from the teachers, ensuring the innovation will be put into practice more readily.

In the Netherlands the innovation is expected to be implemented through new context-based science curricula from 2013 onwards. Science teachers need to be prepared for the pending innovation. The design of curriculum material has been described as a powerful method of teacher professional development (TPD) (Deketelaere & Kelchtermans, 1996; Borko & Putnam, 1996). Unfortunately, not all teachers can be involved in the development of official curriculum materials, when the innovation is implemented nationwide. Additional teacher professional development is therefore necessary.

In this paper the design of a professional development programme aimed at acquiring competence in context-based education for science teachers was described. The design strategy used was derived from the model of Verhagen, Kuiper, and Plomp (1999), that is based on the generic design model Analysis, Design, Development, Implementation, and Evaluation (ADDIE), depicted schematically in Figure 6.1. The analysis and design steps for the model programme were the main subject of this paper.
The following research question was addressed:

What is the content of a successful teacher professional development programme aimed at acquiring context-based teaching competences?

The analysis step consisted of first setting the theoretical background to the programme. Second the research question was answered from a theoretical point of view, by reviewing literature on professional development. Third, the research question was addressed from an empirical viewpoint, by interviewing teachers that had designed curriculum materials for the Dutch context-based innovation. In the design step (from Figure 6.1) the conclusions from the analyses to design a programme for teaching context-based competencies to science teachers were used. This article closed with a reflection and an outlook for the designed programme.

6.2 Analysis

6.2.1 Theoretical background: context-based education and teacher competence

Context-based science education is an approach where applications of science are used as a starting point for developing scientific concepts (Bennett et al., 2007). Important in this approach is active learning by the students, who are required to have a sense of ownership and to have the responsibility for their own learning (Parchmann et al., 2006). The combination of self-directed learning and the use of contexts is consistent with a constructivist view on learning (Gilbert, 2006). People construct their own meanings from their experiences, rather than acquiring knowledge from other sources (Bennett, 2003).
Teachers need to adopt this idea of science teaching and add this to their practical knowledge in order to be able to teach context-based classes successfully. Five teacher competences have been described that are more in demand in context-based education: context-handling, regulation, emphasis, design, and school innovation (De Putter-Smits et al., in pressb). In the following paragraphs these competences will be described.

6.2.1.1 Context-handling

In context-based education teachers are required to be capable to familiarise themselves with the context expressed in the material used in class. This differs from traditional education where the concepts are foremost important and usually explained first before embarking on applications. The required teacher attitude towards contexts is phrased by Gilbert (2006) as: “[...] the teacher needs to bring together the socially accepted attributes of a context and the attributes of a context as far as these are recognised from the perspective of the student” (p. 965). The context should cause a need for students to explore and learn concepts and to apply them to different situations. Teachers have to be able to teach scientific concepts through context-based education (Parchmann et al., 2006) and have to be aware of the need for concept transfer (to other contexts) (Van Oers, 1998).

6.2.1.2 Regulation

In traditional science education the responsibility for learning rests mainly with the teacher. This is associated with strong teacher regulation (Vermunt & Verloop, 1999). Friction between student learning and teacher activities can arise when loose regulative student materials are taught with strong regulation teaching activities and vice versa (Vermunt & Verloop, 1999). In context-based education the responsibility for learning is shared by teacher and learner (Parchmann et al., 2006), requiring teachers to use teaching activities corresponding to shared or loose control strategies. Teachers should be competent in handling these kind of activities, i.e. to guide rather than control the learning process of the students. The use of shared control teaching activities was shown to be effective in evaluating context-based education (Vos et al., 2010).

6.2.1.3 Emphasis

To facilitate the learning of concepts through the contexts presented a different teaching emphasis is necessary as compared to traditional science
education (Gilbert, 2006). Emphasis has been defined by Roberts (1982):

“A curriculum emphasis in science education is a coherent set of messages to the student about science [. . . ]. Such messages constitute objectives which go beyond learning the facts, principles, laws, and theories of the subject matter itself -objectives which provide answers to the student question: “Why am I learning this?”” (p. 245).

Three types of emphases have been described for chemistry education by Van Driel et al. (2005, 2008) based on the work of Roberts (1982) and Van Berkel (2005) on the emphasis of the different science curricula. In a parallel study, a similar classification of emphases to Van Driel et al. (2005) was proposed without specifying toward chemistry (De Putter-Smits et al., 2011). These emphases are also used here:

“a fundamental science (FS) emphasis where theoretical notions are taught first because it is believed that such notions later on can provide a basis for understanding the natural world, and are needed for the students future education; a knowledge development in science (KDS) emphasis where students should learn how knowledge in science is developed in socio-historical contexts, so that they learn to see science as a culturally determined system of knowledge, which is constantly developing; and a science, technology and society (STS) emphasis where students should learn to communicate and make decisions about social issues involving scientific aspects” (De Putter-Smits et al., 2011, p. 36).

The emphasis competence, a KDS and/or STS emphasis, is an important success factor for the context-based innovation (Driessen & Meinema, 2003; Gilbert, 2006) and fits with the teaching activities in a shared regulation classroom.

### 6.2.1.4 Design

From a shared regulation perspective the context-based materials available will not automatically be suited to every classroom or match the need of all individual learners. The active role for the student embedded in the context-based curriculum material require activities like experiments and puts a demand on the time tables. Not all schools will be able to meet these requirements and demands, creating the necessity for the teachers to
redesign the material to the schools’ facilities.
Another consequence of context-based education is the sometimes unpredictable learning demands from the students, causing the teachers to redesign education on the spot. Learning issues students will come across are not generally predictable, requiring teachers to change their lesson plan to the demands of the student. Teachers are therefore expected to (re-)‘design’ the context-based material to their needs. Hence, it is presumed that the educational design will be demanded more of teachers in context-based education than in traditional education.

6.2.1.5 School innovation

Finally, the context-based innovation cannot succeed if it is supported only by isolated teachers (Fullan, 1994). Teachers are to be seen as representatives of this innovative approach in their schools: explaining the ins and outs of context-based education to colleagues, providing support on context-based issues, and collaborating with teachers from other science subjects to create coherence (cf. Boersma et al., 2007; Steering Committee Advanced Science, Mathematics and Technology, 2008). The teachers have to implement the context-based approach together with colleagues of their subject field and even possibly across science subjects to create coherence in the science curricula. In a study into the learning effects among teachers involved in developing ChiK, an increased belief and wish to collaborate within schools is observed. These teachers are also likely to be involved in multifaceted collaborative relationships in their own schools (Gräsel et al., 2006). This competence of teachers collaborating with others in and outside school is the school innovation competence.

6.2.2 Theoretical viewpoint on TPD

To answer the question on the design of a TPD programme for science teachers general characteristics of successful TPD and characteristics specific to acquiring context-based competence are discussed.

6.2.2.1 General TPD

Lasting changes in teaching practice are effected by long-term professional development efforts and can be best fostered by learning in networks, collaborative action research, peer coaching, and the use of cases (Van Driel, Beijaard, & Verloop, 2001). Studies on teacher professional development
generally distinguish two characteristics of successful TPD programmes: process and structural related characteristics on the one side and content related characteristics on the other (cf. Borko et al., 2010; Garet, Porter, Desimone, Birman, & Yoon, 2001; Van Veen, Zwart, & Meirink, 2010). An overview of these characteristics was constructed and is shown in Table 6.1. These proven characteristics will be used and adapted in the design of a programme for TPD towards context-based education.

Table 6.1: Structural and content related characteristics of successful professional development

<table>
<thead>
<tr>
<th>Process and structural</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. the participating teachers are from the same school</td>
<td>e. the content meets teachers personal needs</td>
</tr>
<tr>
<td>b. involvement of academic staff members</td>
<td>f. the focus is on ‘content knowledge’ (i.e. subject matter, new materials/books) and</td>
</tr>
<tr>
<td>c. the programme stretches over a longer period of time</td>
<td>g. on (subject-related) pedagogy and students ways of learning</td>
</tr>
<tr>
<td>d. the participants form a 'study community' rather than just common participation in a workshop</td>
<td>h. the programme provides opportunities for active learning (i.e. reflection, discussion, classroom try-outs, review on the basis of student work)</td>
</tr>
<tr>
<td>i. the learning is coherent with other (learning) activities</td>
<td></td>
</tr>
</tbody>
</table>

To illustrate Table 6.1 the successful Australian PEEL programme is described. The project was founded by a group of academics (characteristic b.) and teachers (characteristic a.) in 1985. It provided an opportunity for teachers to discuss (characteristic h.) disappointing student learning (characteristic g.) as a result from successful lessons (characteristic e.). The teachers could see a direct result from these discussions. This made the programme so successful that when the official two years were over, the teachers continue (characteristic c. and d.) to meet on a regular basis and, moreover, the TPD practice slowly spread to different schools and school levels to become a phenomenon in Australia and other countries (Mitchell & Mitchell, 2005).
6.2.2.2 Context-based education TPD

The effect of teachers working together in small groups in context-based education was shown in research on context-based education. In the German innovation for chemistry (ChiK) and physics (piko) curriculum materials were made or adapted in small groups of teachers from different schools under supervision and assistance of university experts (Parchmann et al., 2006; Suckut & Reinhold, 2007). A change towards context-based teaching of these teachers was visible in their classrooms after three years of designing and using the context-based material (Mikelsis-Seifert et al., 2007).

In the German studies, not all material was made by the teachers themselves; they sometimes used other teachers' materials. In his thesis on professional development of chemistry teachers, Coenders (2010) found that teachers who only use context-based materials do not change their teaching practice towards the expected context-based approach, but teach traditionally adapting the material to their teaching preference. A study by Vos (2010) concurs with this finding. He concluded that the pedagogical approach intended by the designer of the context-based chemistry material is not easily understood and adopted by the teacher that uses this material. Therefore, the design of curriculum material by teachers in small groups should help to ensure the context-based approach is adopted adequately by the teacher, which has also been suggested by Deketelaere and Kelchtermans (1996).

For context-based chemistry education Stolk, Bulte, De Jong, and Pilot (2009b) argue that the design of an innovative study unit would empower chemistry teachers for context-based education. Additionally, to improve the context-based related pedagogical content knowledge teachers need a hands-on classroom based experience, and require sustained support in their ambition to change (Borko & Putnam, 1996). A professional development programme thus needs to focus on changing a teacher’s practical knowledge that “is developed from participating in and reflecting on action and experience” (Fenstermacher, 1994, p. 12).

6.2.2.3 Instructional design models and context-based curriculum design

From the previous paragraphs it is clear that the design of curriculum material can play an important part in teacher professional development. To
aid the design of curriculum material several models have been created that
indicate to a designer which actions to perform in which stage of the design
project. Most models are based on the generic ADDIE design model. In a
survey instructional development models, three different categories are iden-
tified (Gustafson & Branch, 1997): classroom oriented models (the design
of a few hours of instruction), product oriented models (self-instructional
or instructor delivered material), and system oriented model (curriculum
design). The curriculum material made for the innovation falls under the
first two categories.

So far only two instructional models for designing context-based education
have been designed and tested. A classroom oriented model for designing
context-based lessons has been presented by Janssen (2009). In a five-step
model the teacher is guided to design a lesson that is context-oriented rather
than concept-oriented. The model also provides suggestions how to involve
students in the learning process. A product oriented model has been used
in a study where chemistry teachers designed curriculum modules for the
Dutch context-based chemistry innovation (Prins, Bulte, & Pilot, 2011).
This model provides a scheme that explains which learning functions need
to be developed during which phase of the design process. Each learning
function is coupled with activities to be designed under different stages the
author recognises in context-based curriculum material (Prins et al., 2011).

6.2.3 Empirical viewpoint on TPD

The theoretical analysis on TPD discussed in the previous section provides
proven characteristics for successful professional development of teachers.
However, little is known about the specific characteristics of TPD towards
context-based education, as the literature review above has also made clear,
other than the curriculum design activities discussed above.

In the Netherlands science teachers were involved in the design of context-
based curriculum materials that were needed to test innovative context-
based science curricula (biology, chemistry, advanced science, mathematics
and technology, and physics) for upper general secondary education and pre-
university education (years 10-12). Such design experience is a promising
activity for teacher learning (Deketelaere & Kelchtermans, 1996). An em-
pirical study amongst teachers that designed context-based materials was
conducted to add characteristics specifically important for context-based
TPD to the general characteristics that were identified from literature. The
outcomes form the empirical basis for the design of a context-based TPD programme.

6.2.3.1 Research question

The research question for the empirical section was:

Which elements in context-based design teams positively influence the learning of context-based competence in participating science teachers.

In a correlation study data on the circumstances in which teachers involved in the design of curriculum material for the Dutch context-based innovation have worked were related to their context-based teaching competence.

6.2.3.2 Method

Instrument  A composite instrument was used that maps context-based teaching competency of teachers on the behavioural (classroom) and cognitive dimension (De Putter-Smits et al., in pressb). This instrument maps the five teaching competences of context-based education discussed in the theory section of this paper, leading to a total context-based teaching score on each dimension. This study uses only these two scores as indicators for which design team characteristic influences context-based competency. In Figure 6.2 an overview is presented on how the components of the instrument map which competency. The composite instrument consists of both quantitative and qualitative measurements: a teacher-and-class questionnaire, a teacher questionnaire, and a semi structured interview.

The questionnaires are based on international standard questionnaires, such as WIHIC (Dorman, 2003) and CLES (Taylor et al., 1993). The WCQ-questionnaire was validated in a pilot-study and used in a national study to measure the context-handling, regulation, and emphasis competences of science teachers and their classes. Adequacy of fit of the model was found, indicating that the scales selected from the different questionnaires indeed measure the desired context-based construct. The Cronbach’s alpha for these three scales were found to be 0.80 - 0.94 with n=1630 teachers and students (De Putter-Smits et al., in pressa).
The emphasis questionnaire was a parallel version of the one for chemistry teachers designed by Van Driel et al. (2005). The items were divided in three scales, to represent the FS, KDS, and STS emphasis respectively. The items were rephrased to represent more science subjects, whilst for subject specific items equivalents were sought for every science subject involved (ASMaT, biology, chemistry and physics). The questionnaire was evaluated by science teachers that had ties with the university before a nationwide study was undertaken. In total 213 science teachers participated in the study. Cronbach’s alpha for the three scales varied between 0.73-0.90 (De Putter-Smits et al., 2011).

![Table: Overview of the instrument used to measure context-based teaching competence.](image)

The questions in the semi-structured interview determined how much knowledge a teacher had on context-based education, what kind of teaching they effected in their classes, and how they came to possess this knowledge and skill. Where appropriate the answers were given a score by two researchers independently.

The semi-structured interview was extended to include questions on the circumstances of the teachers design team. These questions were based on the findings from literature as summarised in Table 6.1 (characteristics a. to i.).

Characteristic a. was addressed through the question: *Who were part of your design team and what was their background?* The answers were put into categories (teacher, university expert, coach, editor etc.).

Characteristic b. was addressed through the question: *What was the role of the university expert you mentioned?* depending on the answer to the previous question.

Characteristic c. was addressed through the questions: *From when till when did you work on the material?; Do you still work on the material?;*
How many curriculum modules did you (help to) make?; How much time did you spend on designing the material?.

Characteristic d. was addressed through the question: How did the team work go, please elaborate?; Do you still work with the people from the design team?

Characteristic e, f, g, and i were addressed through the question: Why did you join a design team for context-based curriculum materials?, followed by the question: Did any of the following reasons influence you to join: the work focusses on content knowledge, the work focusses on student learning, the work coincided with another activity (study- or other), another personal reason?

Characteristic h. was addressed through the questions: Did you try the material you made in class?; Do you use context-based materials in your classes?; How did the team work go, please elaborate? (from characteristic d.).

The teachers were also asked about the use of instructional design models and their learning on designing curriculum materials: Did you use an instructional design model when designing curriculum material? What is the most important element when designing curriculum material? What would you advise if I started to make curriculum material?

Participants Science teachers who had been involved in the design of context-based materials for biology, chemistry and physics were identified from the author lists in completed context-based curriculum modules. 50 of these designers were approached by phone and email to join the study. Eight ASMaT designers, six biology designers, six chemistry designers, and five physics designers agreed to take part in the study.

Analysis of the empirical study All scoring of the context-based competences from the semi-structured interviews was done by two researchers independently and then the differences were discussed until agreement was reached.

All scores from interview questions and questionnaires were recalculated
into z-scores to allow for the differences in scale. For each of the five context-based competences the average z-scores from the scales of the questionnaires were averaged with the z-scores from interview questions to obtain a score per competence per teacher. The five cognitive competence scores were averaged to obtain the total cognitive context-based competence score. The three behavioural cognitive competence scores were averaged to obtain the total behavioural context-based competence score (De Putter-Smits et al., 2009, in pressb).

The answers to questions related to characteristics were expressed in a number. Thus for each of the 25 teachers the number of teachers in their respective design teams was noted, as were the number of coaches, university experts, technicians and so on.

Using field coding (Miles & Huberman, 1994) to identify categories, important elements when designing curriculum materials were identified. One important element was for instance time. It was mentioned by all designers and the thus found category time was tallied to 25. A similar strategy was used for all important factors identified from the semi-structured interviews.

Next the total cognitive and behavioural context-based competence scores were correlated with all the characteristics (a. to i. from Table 6.1) and with all important elements of designing context-based materials. Thus influencing characteristics on context-based teaching competence were identified. The other learning expressed by the teachers was analysed using field coding (Miles & Huberman, 1994)

6.2.3.3 Results

The results of the correlations between context-based competence score and characteristics of successful professional development (as detailed from Table 6.1 in the method section) are presented first. Then the results on specific characteristics for the design of curriculum materials are presented, followed by the results on other learning.

All teachers indicated that their learning of what context-based education entails was initiated by their design experience.

No significant correlations between the total behavioural competence score and the characteristics for successful TPD were found. In Table 6.2 the significant correlations between cognitive context-based
competence and characteristics for successful TPD are given. Other characteristics from Table 6.1 that were detailed in the method section did not correlate significantly with cognitive context-based competence.

Table 6.2: Correlations for characteristics of successful TPD in design teams for context-based curriculum materials and cognitive context-based teaching competencies in designers (n=25)

<table>
<thead>
<tr>
<th>General characteristic for successful TPD</th>
<th>Detailed characteristic for successful TPD</th>
<th>Total context-based score</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. The teachers participating are from the same school</td>
<td>Number of teachers in design team</td>
<td>-0.44*</td>
</tr>
<tr>
<td>c. The work stretches over a longer period of time</td>
<td>Amount of material made</td>
<td>0.44*</td>
</tr>
<tr>
<td></td>
<td>Duration</td>
<td>0.44*</td>
</tr>
<tr>
<td></td>
<td>Continuance</td>
<td>0.48*</td>
</tr>
<tr>
<td>h. Opportunities for active learning</td>
<td>Use of context-based material in class</td>
<td>0.65**</td>
</tr>
</tbody>
</table>

*aCorrelation is significant at the 0.05 level (two-tailed)

**Correlation is significant at the 0.01 level (two-tailed)

a. teachers participating are from the same school A negative significant correlation was found for (increasing) number of teachers working together on material and context-based competency score (see Table 6.2). The teachers from these large curriculum design teams were the same ones who, during the interview, strongly advertised the need for solid agreements on the work to be done when asked to report ‘other learning’ in curriculum design teams.

c. the work stretches over a longer period of time Of the process and structural related characteristics for TPD time (c. in Table 6.1) was the most apparent in two ways. First it was mentioned by all interviewed teachers as an important factor for the actual design process. Second, the amount of time spent on designing materials was positively related to context-based competency. The more time that was spend (duration) on designing material, the more context-based teaching competency develops in the teacher (significant correlations given in Table 6.2).
A significant correlation with a higher competency score was also found for ‘amount of material made’ and ‘still continuing to design material’ (continuance). Looking closer at the designers involved in more study modules over longer periods of time, these teachers are now involved in disseminating the innovation to the field. They are assisting the design of more context-based modules as a coach with new teachers and even recording their experiences in books on the Dutch context-based innovation.

h. opportunities for active learning  Of the content related characteristics for TPD active learning (h. in Table 6.1) was the most apparent. Active learning here was represented by the use of context-based material in the classroom. The context-based teaching materials made by the teachers were used in various ways: some teachers used only their own material, some used their own materials and that of others, some used their own materials alongside a non-context-based method, some did not use context-based materials at all.

The (continued) use of (self-designed and other) context-based materials in the classrooms, usually coincided with the time the teachers started designing and was positively related to context-based competency (see Table 6.2). Besides the quantitative analysis, some designers mentioned during the interview that only when they first used the materials in class it became clear to them how the pedagogic innovation actually worked: “It is not ‘alive’ before you have tried the material” (quote from semi-structured teacher interview).

In Figure 6.3 the different elements the designers found most important when designing context-based curriculum materials are presented as well as the number of times it was mentioned.

According to 10 out of the 25 teachers interviewed the most important element when designing curriculum material was having or constructing a heuristic structure that structures the design work for them. When asked this structure included for some a learning continuity pathway (threading together the concepts) for the intended curriculum module, a clear time schedule with deadlines for others, or a format indicating what kind of information in the curriculum module should be in which position. None of the teachers with curriculum design team experience had used an
Instructional design model when designing material. When asked they sometimes indicated they had a *scheme* of *schedule* to work by, or in one case that they had devised their own *rules of thumb*.

According to the teachers interviewed, the second most important element when designing curriculum materials were the specific *members* of the curriculum design team (mentioned by 5 out of 25). The designers had balanced views on who should be in a design team. For instance: “I discovered I am very good at writing text, but I really need help from someone to make useful exercises. Next time I am designing something I will ask [name] to work with me again, we make a good team” (quote from semi-structured interview). And: “The guy from the university had nothing to do with it, he looked at our work once and gave useless advice. I don’t think he was interested. I went to a masterclass and learned more about what I needed to know on the context we were using than from him. Next time I want to select the context-expert myself” (quote from semi-structured interview).

The third most important element when designing curriculum material according to 4 out of 25 teachers interviewed was to take a *student perspective* on what you are making (see Figure 6.3). By this term the teachers
meant that when designing one should look through the students’ eyes to what would interest them, what kind of activity or context they would find attractive, what would stimulate them to work with the curriculum material and so on. This focus was according to them important in the design of curriculum material, rather than a prerequisite to a TPD programme as suggested in g. in Table 6.1.

The teachers experienced in designing curriculum material indicated that to their opinion a course in curriculum material design would not have been necessary: they learned on the job by trial and error.

6.2.3.4 Conclusions on the empirical study

The number of teachers was related to a lower context-based competency. This effect probably points to an optimum number of teachers working together. The data and number of designers in this study do not allow for the determination of such an optimum number. It does however mean that the number of teachers working together should be considered carefully when designing a TPD programme.

An important factor mentioned was time. The actual process of designing materials, trying them and adjusting them takes up more time than the teachers had available. Spending more time also made the teachers more competent. Some teachers in our study apparently classified as experts, since they have started to coach others and write books about designing context-based materials.

The use of context-based material in class as a form of active learning correlated with context-based competency. Other research suggested that the use of context-based material in class is important to learn how to teach context-based (Coenders et al., 2008). Using context-based material in class can therefore be seen as a specific characteristic for successful learning of context-based education.

For the design of curriculum materials it is apparently important to provide the teachers with some kind of heuristic structure. This can be done in two ways: providing strict deadlines and activities and/or using instructional design models such as Gustafson and Branch (1997) describes which aids the designers in keeping to the learning pathway they envision and helps the teachers to analyse when what kind of activity should be incorporated in the material. The use of an instructional design model also
prevents teachers from skipping the analysis phase in designing material, which speeds up the writing process, and it leads to more appreciated curriculum materials (Hoogveld, Paas, Jochems, & Van Merriënboer, 2002). In the analysis phase of such an instructional design model, the student perspective should be taken into account as was indicated by the designers in this study.

6.3 Design

In this part the design for a TPD programme aimed at acquiring context-based teaching competence is described. The elements of the programme are based on the theoretical and empirical study. Each element of the design is described in detail. For convenience the elements are discussed in the same order as the characteristics for successful TPD, first presented in Table 6.1.

Considering the strong indications from literature (theoretical viewpoint) and the experiences of teachers with curriculum design team experience (empirical viewpoint), the design of curriculum materials is proposed as the participants’ activity in the TPD programme. As was concluded from the empirical study, such an activity benefits from an instructional design model. This can be provided by using context-based design model such as used by Prins (2010) or Janssen (2009) depending on the extent of the curriculum material to be made (entire curriculum module or one or two lessons). The time-schedule with deadlines suggestion from the designers could be provided by sending participants to the programme timely e-mails with a summary of common problems the participants encountered so far and encouraging them to meet the deadlines of the programme (Visser, Coenders, Terlouw, & Pieters, in press).

6.3.1 Process and structural characteristics

a. The TPD programme is designed for pairs of science teachers from the same school (characteristic a. from Table 6.1 and empirical result in Figure 6.3). Since using context-based materials made by others was found not to be effective in learning to teach context-based education (Coenders, 2010), the participants of the programme should each have the intention of writing their own context-based curriculum material for their own science subject. The intention is to allow science teachers from all the different science subjects into the programme. This would improve the understanding of the
differences between the science subjects and allows for cross-pollination of ideas from the different science subjects. It can also help to establish the desired collaboration context-based education requires.

b. During the programme meetings (university) experts on context-based education, design models and writing curriculum materials are asked to provide their expertise. These experts should be available and offer feedback to the participants throughout the programme.

c. and d. The programme should continue for at least two years. This means that the participants can use the material they designed in class at least twice. It can thus be fully adapted to teaching practice and advice from experts can be sought until the material is completed. Ideally the programme should lead to a community of learners that in time can sustain itself unaided by experts (cf. Mitchell & Mitchell, 2005).

6.3.2 Content characteristics

e. The teachers that subscribe to the programme should do so on a voluntary basis. Their expectations of the programme need to be listed before the programme starts, so the content can be adapted where necessary to the teachers’ specific needs.

f. Inherent to the programme is the focus on content knowledge: teachers are given the opportunity to design context-based material for their own classroom under the supervision and guidance of experts. The programme should ensure the participants become aware of all five context-based teaching competences. The context-based teaching activities can be made explicit by an expert on context-based education during the programmes meetings. Examples on paper and on video of the differences between the standard science teaching approach and the context-based approach can help participants to experience the context-based teaching practice. This can also be done by providing feedback on ideas the teachers generate during a brainstorm phase, feedback on the materials the teachers make and feedback on the classes they teach.

g. During the programme attention should be paid in the materials, the talks and the discussion to ‘student ways of learning’ and the student perspective of the material the teachers are designing. The choices for contexts
to use the participants make, the kinds of activities the students should be engaged in should be viewed from the students’ perspective. The participants should be aware that context-based education is based on a shared or loose control teaching strategy whereby the students’ will to learn should be activated more.

h. The programme requires the participants to learn actively: most importantly the curriculum material the participants make should be tried in class. Moreover, they are expected to comment on each other’s work and visit each other’s classrooms during the execution of the study module designed. Meetings should contain brainstorming sessions, discussions, reflection, feedback on ideas, materials and classes taught.

i. This characteristic is addressed in the sense that the Dutch innovation of the science subjects is expected to start in 2013. The programme prepares teachers for this innovation. Another incentive to join this programme is that teacher professional development has become a topic in the Netherlands, since the initiatives for a qualified teacher register have begun.

For the participants the programme will be a consecutive set of meetings taking them through the steps of the model, such as presented in Figure 6.4. Ideally, the meetings continue for at least two school years and should lead to a community of teachers that come together to discuss curriculum material they made, or intend to make, on a regular basis.

6.4 Considerations, limitations, and outlook

The model of the programme presented here aims at all science subjects, including not only the traditional subjects biology, chemistry and physics, but also the newer subjects as ‘public understanding of science’ (also known as general science) and applied science, mathematics and technology (AS-MaT). This implicates that a general view on context-based education is used. The steering committees have agreed on a general view on what context-based education entails (Boersma et al., 2006) that is more abstract than the definition presented in this paper. However, the committees differ widely in the details of context-based education for their subject.

Although the programme is meant for teachers from all science subjects, it does allow for subject specific elements, such as the differences in nature
of experiments between the different science subjects, on an individual basis. For participants the general nature might be hindering their desire to design ‘proper’ context-based material for their subject, when no colleague from the same subject is present. On the other hand it can be argued that it is beneficial since it provides the participants with a broader perspective, facilitating collaboration with other science subjects and connects to the practice of teachers teaching more than one science subject.

One of the prominent characteristics is *time*. The programme ideally runs for two years or more to allow for continuing teacher professional development. In one such programme it was recorded that teachers only changed their classroom teaching noticeably toward context-based education after three years (Mikelskis-Seifert et al., 2007). However, the one thing teacher do not often have is time. Effecting such a programme without funding from the participants’ schools or from outside is difficult (Fullan, 1994). This can lead to a shorter programme, which in turn is expected to be less successful in TPD.

To establish the effects of the TPD programme designed here and to prove and improve the set up, the execution of the programme should be studied in detail by monitoring participants. This could be done using the instrument
Design of a professional development programme

to map context-based teaching competencies developed in a previous study (De Putter-Smits et al., in pressb). Design research on the TPD programme (cf. Gravemeijer & Cobb, 2006) could be appropriate to study the effects of this programme and to improve the learning outcomes of the participants.

A first attempt to professionalise science teachers using this model has taken place from September 2010 onwards. The learning outcomes of the participants as well as an evaluation of the model used are part of the research that is coupled to the TPD programme. A case-study method has been chosen to explore the outcomes. So far, the participants show an increased understanding of what context-based education requires of them. The participants indicate that classroom implementation is challenging.
Chapter 7

A case study of a professional development programme aimed at connecting context-based teaching competency with the design of instructional materials

Article submitted.

abstract

A professional development programme for science teachers aiming at developing context-based teaching competencies through the design of instructional materials was developed and executed. Five science teachers from different science subjects and differing in teaching experience took part in the programme whilst their progress in context-based teaching competency was monitored. The learning of the teachers was mapped in the cognitive and behavioural (classroom) dimension and analysed for differences in learning between experienced and less experienced teachers and for differences between science subjects. A change in context-based teaching competencies
in the cognitive and behavioural dimension has been found. Key elements of the programme are feedback and input both from experts and other participants, and seeing oneself teaching. Recommendations for improvement on the programme are made.

7.1 Introduction

A trend in science teaching in the upper levels of secondary education in Germany, the UK, and the Netherlands is to use the context-based pedagogical approach (Bennett et al., 2005; A. Bulte, Westbroek, & A. Pilot, 2006). A context-based approach to science education has been advocated both from a changing learning theory perspective (Greeno, 1998) and the call to not only educate students who are interested in science, but also provide a science education for the general public (Solomon & Aikenhead, 1994). New science curricula in the Netherlands involving the context-based pedagogical approach are expected to be implemented from 2013 onwards. Context-based materials for these new science curricula are freely available online (cf. www.nieuwescheikunde.nl). Printed books comprising a full context-based science curriculum are not yet available.

To spread the context-based innovation further to the teaching field, initiatives for chemistry education have been taken to involve teachers in the re-design of existing (online) materials in collaboration with experts to the teachers’ personal needs (cf. A. Bulte, 2011; Pol, 2011). Designing instructional materials in collaboration with educationalists is expected to be a powerful source for teacher professional development (Deketelaere & Kelchtermans, 1996). In this study we combine the need for new (context-based) material and the powerful effect of collaborative design work on teacher professional development and the need to acquire context-based educational skills for the pending curricula by setting up a programme for teacher professional development where the goal is to design context-based materials for the teachers’ own classrooms. In the case study presented here the change in context-based teaching ability in the participating science teachers is described and linked to the programme’s design.

7.2 Theoretical background

The goal of the teacher professional development programme is to develop the participants’ practical knowledge (Fenstermacher, 1994) that is necessary for teaching using the context-based approach. This kind of knowledge
“is developed from participating in and reflecting on action and experience. [...] [it] is generally related to how to do things, the right place and time to do them, or how to see and interpret events related to one’s actions.” (Fenstermacher, 1994, p. 12). In teacher professional development programmes two kinds of characteristics are identified: content related and process and structural. In successful teacher professional development programmes the content is situated in (teaching) practice and is focussed on student learning (Borko et al., 2010).

The content related characteristics of our teacher professional development programme are aspects of (teaching) context-based education. The definition of context-based education we use in this study is based on the descriptions of context-based education provided by others (cf. Bennett et al., 2007; Gilbert, 2006; Parchmann et al., 2006): a context-based science education is an approach in which contexts that are meaningful to the student are used as the starting point for the learning of scientific concepts, the students are responsible for their own learning (active learning) in an environment that can be (re-)designed by them and their teacher to their needs, interacting with other science subjects or outside-school organisations where appropriate (De Putter-Smits et al., in pressb).

From our definition of context-based education we derived the teaching competencies a teacher relies on to teach context-based education: context handling, regulation, emphasis, design, and school innovation (see Table 7.1) (De Putter-Smits et al., in pressb).

The competency of context-handling includes: the choice of which context to use, how to use this context, which concepts are appropriate in the context, and how to make concepts transferable to other contexts. We consider that in principle any context recognisable by students is suitable, provided that the concepts follow from the context in a logical manner (Gilbert, 2006). Attention should be paid that the concepts learned within a context should be recontextualised (Van Oers, 1998) which means that students can use these concepts in other contexts as well. Students should be immersed in the context (Gilbert, 2006)) by giving them a role (e.g. executive, engineer, researcher). These role-playing activities makes them more responsible for their own learning, a competency we named regulation. The responsibility for learning is shared, allowing the students to construct their own learning process under the guiding influence of the teacher (Vermunt & Verloop, 1999). This contrasts with the standard science education practice
where the teacher controls the learning process more strongly (Bennett et al., 2007).

Our definition of context-based education implies that the question why students should learn certain concepts is answered by linking the concepts to subjects close to the students’ interest. In terms of emphasis (Roberts, 1982) the approach requires teachers to change in teaching emphasis from the predominant fundamental science emphasis, toward a knowledge development in science or science, technology and society emphasis (see Table 7.2).

Teachers should be able to accommodate this different view on science teaching in order not to frustrate the process (Van Eekelen, Vermunt, & Boshuizen, 2006). For our teacher professional development programme to be successful, this means teachers should be interested in and willing to learn about context-based education.

In the innovation teachers are seen as representatives of the innovative approach in their schools: explaining the ins and outs of context-based education to colleagues, providing support, and collaborating with other science subjects to create coherence (cf. Boersma et al., 2007; Steering Committee Advanced Science, Mathematics and Technology, 2008). Teachers that also design instructional materials are likely to be involved in multifaceted collaborative relationships in their own schools (Gräsel et al., 2006). The

<table>
<thead>
<tr>
<th>Competency</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Context handling</td>
<td>Handling contexts, establishing concepts, making concepts transferable for students</td>
</tr>
<tr>
<td>Regulation</td>
<td>Promoting student active learning; guiding teacher role</td>
</tr>
<tr>
<td>Emphasis</td>
<td>Explaining science through knowledge development in science or science, technology and society</td>
</tr>
<tr>
<td>Design</td>
<td>Redesigning material to classroom needs, active learning requires designing ‘on the spot’</td>
</tr>
<tr>
<td>School innovation</td>
<td>Representing the innovative approach in school</td>
</tr>
</tbody>
</table>

Taken from De Putter-Smits et al. (in pressb)
Table 7.2: Emphasis definitions

<table>
<thead>
<tr>
<th>Emphasis</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fundamental science (FS)</td>
<td>A theoretical notion is established first as a basis for further education</td>
</tr>
<tr>
<td>Knowledge development in science (KDS)</td>
<td>The student learns how scientific knowledge is developed in socio-historic contexts</td>
</tr>
<tr>
<td>Science, technology and society (STS)</td>
<td>The student is expected to communicate and make decisions about social issues involving science</td>
</tr>
</tbody>
</table>

1 Definition taken from (Roberts, 1982, p. 245)
2 Definitions taken from 3

The process and structural characteristics for successful teacher professional development programmes include teacher active learning and building a community of learners (Borko et al., 2010). Since active learning by the students is an important element of context-based education, to ‘teach as you preach’ in professional development programmes (Borko & Putnam, 1996) thus includes active learning for teachers. Designing instructional materials is an active form of learning especially when ample opportunities for feedback and reflection are offered to the learner (cf. Garet et al., 2001; Putnam & Borko, 2000). Educational design is also an important element in our definition of context-based education strengthening our choice of designing educational material as a learning activity.
7.3 Research setting and research questions

To explore the possibility of improving context-based teaching practice through designing context-based materials for their own practice, we designed a professional development programme for science teachers. The learning of the participants of this programme was monitored. The programme was aimed at teams of teachers from different science subjects (biology, chemistry, physics, or public understanding of science), from the same school designing for the upper levels of secondary education. The programme took place from September 2010 to February 2011. There were three formal meetings at the institute and one informal meeting between teachers when visiting each others’ classroom (see Figure 7.1). The first meeting started with an interactive talk by a context-based education expert on successful context-based materials using both the material and the videoed practice. The differences between standard teaching and context-based teaching methods were discussed. The next speaker introduced a context-based educational design model (Prins, 2010) meant to assist the teachers in their design of materials. The participating teachers were then asked to brainstorm in pairs during the first meeting on which class, which context, and which concepts they would choose to make the material for. The final speaker addressed principles and pitfalls of the writing process itself.

Figure 7.1: Outline of the context-based materials design programme

The teachers were required to hand in their first ideas or first drafts of the material (context, student assignment, learning goals) they made before the second meeting. The first author and the context-based education expert discussed these materials together, and made a list of recommendations for each participant. All recommendations were made in line with the context-based nature of the materials the teachers were trying to design. During the second meeting a short recapitulation of the main elements of context-based education was given by the first author. Next the context-
based education expert discussed the feedback with each participant in turn, asking the opinion and ideas of the other participants first before giving the pre-discussed recommendations in a reflective discussion with each participant.

All participants then designed and taught their context-based classes (10 to 15 50-minute lessons). The participants were paired and expected to visit each others’ classrooms once during the teaching of the context-based material. They were asked to discuss their visit together and report on that in the third meeting. The first class where the material was used (focal event; (Vos, 2010)) was filmed for each participant. A copy of this film was sent to the participants. The participants were required to reflect on their effected context-based teaching using examples from this film. The researcher and the expert also evaluated the film footage on the context-based education each teacher managed to put into practice previous to the third meeting. During this meeting each teacher was asked to report their reflection on the context-based class taught and input from the other participants was asked. Next the expert discussed the pre-agreed opinion on the class filmed with the participants, in such a fashion they could formulate improvements on both their classroom performance and the materials they made.

The research questions in this case study are:

1. Is there a change in the context-based teaching competences in participating teachers due to the programme we designed? If so:
   a. is this change in the cognitive and/or in the behavioural dimension?
2. what elements in the programme can be adjusted to improve the change in competencies?

Issue 1a was chosen because the teacher professional development programme is aimed at changing classroom practice (behavioural dimension). Cognitive change can occur within one year of context-based teaching (Mikelskis-Seifert et al., 2007). However, a period up to three years of designing and teaching (physics) has been recorded before a change in teaching practice was visible (Mikelskis-Seifert et al., 2007). The innovation in the science subjects in the Netherlands is expected to be implemented from 2013 onwards, making it necessary for teachers to learn how to use the context-based approach. A validated programme for all science subjects is a valuable addition to the professional development programmes in this area. Hence issue
2 was chosen.

7.4 Method

To map the learning of the participants to the professional development programme we collected data that provided indications of the context-based competences of the teachers. A schematic overview of the programme and of the data collected is given in Figure 7.2.

![Figure 7.2: Schematic representation of the context-based materials design programme and data collection](image)

The opinion of the teachers reflected during the interviews, the teacher questionnaires, in the logbooks and the written material on how to conduct the classes is taken to provide information on the cognitive dimension. The video observations of the teachers whilst teaching and the student opinion from the student questionnaires is taken to provide information on the behavioural (classroom) dimension.

**Interviews** Previous to the programme and after the programme we conducted semi-structured interviews with the participants. The pre-programme interview consisted of questions about the teachers’ context-based education competences and how they put these into practice in their schools. The post-programme interview contained similar questions also asking how (if any) changes in context-based competency had come to pass. Thus changes in cognitive context-based teaching competency (and their source) could be detected. The post-programme interview also included a story-line question (Taconis et al., 2004) on context-based competence. The teachers were asked...
to draw their learning curve starting from the beginning of the programme up to that moment (x-axis) versus their experience as context-based teacher (y-axis) from ‘beginner’ up to ‘expert’. The transcripts of these interviews were sent to the teachers for comments.

**Emphasis questionnaire**  At the start of the first meeting and at the start of the final meeting the teachers were asked to fill out a questionnaire on teaching emphasis. This questionnaire measures the teachers’ opinion on emphasis (De Putter-Smits et al., 2011). The scores on FS, KDS and STS before and after the programme can be compared to detect any changes. A difference of more than 0.5 between the pre- and post scores was taken to be a significant (half the standard deviation of a national sample (De Putter-Smits et al., 2011) which equals a medium effect size) change in the cognitive dimension, indicating an emphasis competency change.

**Context-based learning environment questionnaire**  At the start of the first meeting a teacher and student questionnaire (CBLE) on context-based classroom behaviour was taken. The same questionnaire was distributed again to the teachers and their students at the end of the executed context-based classes. The development and validation of this CBLE questionnaire has been described in De Putter-Smits et al. (in pressa). The different scales measure the context-handling, regulation and emphasis competency. A change in score on these scales of more than 0.30 (teachers) was taken to be significant (half the standard deviation of a national sample (De Putter-Smits et al., in pressa) which equals a medium effect size).

**Logbook, video and materials**  After each meeting participants were asked to fill out a logbook with reflective questions on the meeting. Also a written reflection of the participants on the teaching (after viewing their own videoed class) of the newly-made material was collected. The formal meetings where videoed and the brainstorm sessions between teachers where recorded. The first lesson of each participant’s context-based class was videoed. The context-based materials the teachers made were collected (first draft, final versions). The logbooks, videos and materials were analysed for key episodes or phrases where the context-based competences (see Table 7.1) were visibly used by the participants. Two researchers independently marked these episodes. For instance in the video of the second meeting teacher E took over the role of
the expert and said: “And which ‘role’ do your students have in this jeans factory?” The kind of regulation she has associated with context-based education is strongly visible at this point.

**Analysis** For each participant the change in each context-based competence was mapped in turn, comparing pre-course opinions and questionnaire scores with opinions voiced during and after the course. The total change toward context-based education the researchers found was compared with the storyline on context-based education the participating teachers were asked to draw and describe during the semi-structured final interview. In the analysis attention was paid to alternative sources of influence on the change in context-based competences. The resulting changes in context-based competences for all participants are discussed below.

**Participants** Initially, six teachers joined the programme; here recoded into teacher A - F (see Table 7.3). Four teachers were of the same school, from different science subjects. This school follows the Steiner-Waldorf educational system founded by Rudolf Steiner. That school’s system is different in that *all* students, every school year follow a three-week period of *each* subject, including science subjects. These periods contain concepts and contexts laid down by Rudolf Steiner, but educational material is usually made every year by the teachers themselves. Besides this periodical education the school has adopted the main Dutch educational system in that it provides year round education in the sciences leading up to the national examinations. Teachers are relatively free to choose the manner of teaching in the three-week period, which made it possible to fit self-made context-based material in the curriculum. The other two teachers were from regular but different schools. One teacher worked at both the Steiner-Waldorf school and a regular school. After the first meeting one teacher dropped out of the programme due to lack of time to spend on the design of the material.

### 7.5 Results

In this section we first provide a general overview of the programme’s proceedings and the changes in context-based competences in our participants. Next we will discuss the change per teacher. Concluding our results is the answer to research question 2.
Table 7.3: Participant characteristics

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Experience (yrs)</th>
<th>Subject(s) taught</th>
<th>School</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>32</td>
<td>Chemistry, Public understanding of science</td>
<td>College1</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>Physics</td>
<td>College1</td>
</tr>
<tr>
<td>C*</td>
<td>10</td>
<td>Physics</td>
<td>College1</td>
</tr>
<tr>
<td>D</td>
<td>20</td>
<td>Biology, Public understanding of science</td>
<td>College2</td>
</tr>
<tr>
<td>E</td>
<td>19</td>
<td>Biology, chemistry</td>
<td>College1, College3</td>
</tr>
<tr>
<td>F</td>
<td>5</td>
<td>Chemistry, Science</td>
<td>College4</td>
</tr>
</tbody>
</table>

*Teacher C left the programme and the study after the first meeting

In Table 7.4 an overview is provided of all data we collected. Teachers D and F did not manage to visit each other’s classrooms due to illness and lack of time. Teacher E was paired with teacher C who left the study and later during the school year left the school. This loss of partner and colleague also resulted in her not having the time in class to try out the material she had made.

Table 7.4: Data collected per teacher

<table>
<thead>
<tr>
<th>Teachers</th>
<th>Interviews</th>
<th>CBLE questionnaire</th>
<th>Emphasis questionnaire</th>
<th>Feedback forms</th>
<th>Logbook</th>
<th>Material</th>
<th>Video</th>
<th>N-pre/post CBLE questionnaire</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>pre/post</td>
<td>pre/post</td>
<td>pre/post</td>
<td>pre/post</td>
<td>4/4</td>
<td>2/2</td>
<td>yes</td>
<td>20/19</td>
</tr>
<tr>
<td>B</td>
<td>pre/post</td>
<td>pre/post</td>
<td>pre/post</td>
<td>pre/post</td>
<td>4/4</td>
<td>2/2</td>
<td>yes</td>
<td>8/7</td>
</tr>
<tr>
<td>D</td>
<td>pre/post</td>
<td>pre/post</td>
<td>-</td>
<td>-</td>
<td>3/4</td>
<td>3/4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>E</td>
<td>pre/post</td>
<td>-</td>
<td>-</td>
<td>pre/post</td>
<td>3/4</td>
<td>3/4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>F</td>
<td>pre/post</td>
<td>pre/post</td>
<td>pre/post</td>
<td>pre/post</td>
<td>-</td>
<td>-</td>
<td>yes</td>
<td>-</td>
</tr>
</tbody>
</table>

Students: 20/19 8/7 25/22 - 20/21
A change in teachers context-based competences becomes visible when comparing the pre-programme and the post-programme interview data. The change in cognition is noticeable also from the reflections during the meetings and in the logbooks. For some teachers also a change in classroom behaviour is noted by their students. The trend and nature of the change per teacher is described in Tables 7.6 to 7.10.

When analysing the CBLE questionnaires of all students (combined for teachers A to F) the teachers in general have changed towards more context-based teaching. However, the effect size of the change in scores is small (Cohen, 1988) as shown in Table 7.5.

<table>
<thead>
<tr>
<th>Competency</th>
<th>Pre</th>
<th>Post</th>
<th>ES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Context handling</td>
<td>2.95</td>
<td>3.07</td>
<td>0.13*</td>
</tr>
<tr>
<td>Regulation</td>
<td>3.29</td>
<td>3.51</td>
<td>0.26**</td>
</tr>
<tr>
<td>Emphasis</td>
<td>2.81</td>
<td>3.15</td>
<td>0.32**</td>
</tr>
</tbody>
</table>

*no significant effect  
**small effect

All teachers indicated in their story-line graph that their competency in context-based education had increased. They all decided to use the meetings as reference points for the time scale. Some teachers also indicated the classroom teaching of the material they had made as a reference point. For teachers A, D and F the story-line graph started at the intermediate level and ended closer to the expert level. The other two teachers situated themselves as a beginner, then increasing in competence. Four teachers indicated an increase in competency after each meeting and after teaching the context-based class (teachers A, B and F). One teacher (D) indicated a steady level increase with the remark that ‘the design work had continuously been on her mind’. An example of the graphs the teachers drew of their experience is given in Figure 7.3. The trend of the graphs of each participant is comparable to the researcher observed change in context-based teaching competency of the participants.

In the semi-structured interviews before and after the programme the
teachers were asked to indicate where they had acquired their knowledge on context-based education. Comparing the answers given to this question from the before and after interviews lead to no other sources of knowledge during the period of the programme, indicating all change in knowledge was instigated by the programme.

7.5.1 Teacher A

Teacher A is one of the founding teachers of the Steiner-Waldorf school, with over 30 years of experience in teaching. He had positioned his knowledge of the context-based innovation for his field (chemistry) inline with the Steiner philosophy.

“You use contexts from modern developments in chemistry and you work from the principles of the phenomenology. You work from what is going on in the world towards chemical concepts.”
Table 7.6: Description of the context-based competence change in teacher A

<table>
<thead>
<tr>
<th>Competency</th>
<th>Description of change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Context handling</td>
<td>Small cognitive change on context definition and need for immersing himself into the context; no behavioural change according to students.</td>
</tr>
<tr>
<td>Regulation</td>
<td>Change in awareness of different regulation; blind spot on how to effect this; significant behavioural change according to students.</td>
</tr>
<tr>
<td>Emphasis</td>
<td>Small cognitive change towards STS/KDS during classroom teaching; general opinion unchanged but high in comparison to Dutch standard*; significant behavioural change according to students.</td>
</tr>
<tr>
<td>Design</td>
<td>Cognitive change: design starts from the context; differentiating between different students is important; make meaningful material for all kinds of students.</td>
</tr>
<tr>
<td>School innovation</td>
<td>Desire to evaluate each other’s ideas in future; contacts with experts were established; official collaboration is hindered by time constraints.</td>
</tr>
</tbody>
</table>

* Compared to data taken from De Putter-Smits et al. (2011)

(source: pre-course interview)

After the programme this had changed to:

“Education that centres around a realistic theme or given situation, where all kinds of multidisciplinary matters are linked and that together make one, a kind of anchoring point, where everything can be traced back to.” (source: post-course interview)

This teacher realised during the programme that knowledge on the context he was teaching was important. He immersed himself in the context by following an external course on astronomy, the context he was using. His attitude towards the context has changed, which is also visible from his view on designing materials.

“Now, I let myself be guided by the context when designing
Steiner’s view on science seems to coincide with a KDS emphasis as presented in the theory section. This would explain the teacher’s relatively high score on the general emphasis questionnaire compared to the Dutch teachers’ average score (source: pre- and post- emphasis questionnaire).

The experienced teacher admitted in his logbook (source: 3rd logbook) that shared regulation and how to effect it is his blind spot. He indicated that reformulating all his assignments leaving the students more room to develop their own ideas was a key learning point, for which he would appreciate more assistance from the researchers coming school year (source: post-course interview).

The material he used in the programme was intended for all students (not only those who chose science) in the upper levels of secondary education for the three-week period teaching of public understanding of science. He had used the material in the previous year and tried to change it towards context-based material, without letting go of the original ideas and all the effort that was already in the material. This probably explains his difficulties in reformulating assignments.

7.5.2 Teacher B

Teacher B is new to the teaching practice and had “no clue” what a context required. “The daily goings on? [...] Maybe the concepts are more towards what the students want to know?” (source: pre-course interview)

After the programme she was able to elaborate more:

“A context is an authentic practice; all contexts are suitable for these assignments. I guess the concepts need to be broad enough for all students to find their own way [through them]. I keep the context in mind now, when I prepare my classes (source: post-course interview).”

Teacher B also expressed concerns about the guiding teacher role she needed to adopt in the class. Her class was a lower level pre-professional education class, with only eight students, two of which had interest in science. She indicated during the third meeting she had to “guide the students a lot, ‘cause they simply did not seem to get a move on (source: transcript
Table 7.7: Description of the context-based competence change in teacher B

<table>
<thead>
<tr>
<th>Competency</th>
<th>Description of change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Context handling</td>
<td>Cognitive change on context definition; concepts need to be considered carefully; context first then possible concepts; small change in classroom behaviour according to students.</td>
</tr>
<tr>
<td>Regulation</td>
<td>Cognitive change on the kind of regulation expected; coherent use in interviews, on class video and reflection logbooks; significant change in behaviour according to students.</td>
</tr>
<tr>
<td>Emphasis</td>
<td>Significant cognitive change towards STS/KDS teaching; high score on emphasis compared to the general Dutch opinion; significant behavioural change according to students.</td>
</tr>
<tr>
<td>Design</td>
<td>Cognitive change: design starts from the context, in accordance with Steiner’s views; developed her own model for design: during brainstorm a spider web with the context as central starting point to create ideas; ideas for materials for other classes.</td>
</tr>
<tr>
<td>School innovation</td>
<td>Clear ideas on how much collaboration is possible; official collaboration is hindered by time constraints.</td>
</tr>
</tbody>
</table>

* Compared to data taken from De Putter-Smits et al. (2011)

from video 3rd meeting).” She was pleasantly surprised at the results of the assignments.

“I really tried not to tell them what to do. Just to guide them, point them where the information they needed could be. It was really difficult. […] I was really surprised at the results, considering (source: transcript from video 3rd meeting).”

Her idea of the kind of assignments and student control has been changed during the programme from: “students should control their own learning process, look up stuff themselves; the teacher is more of a coach, not the all-knowing narrator”, towards a more operational definition: “Students work
on open-ended assignments, using their own structure, are actively involved rather than sitting there as ‘consumers’.” (sources: pre- and post-course interviews)

Teacher B experienced that designing your own material has an added value to the students. She has become enthusiastic about designing her own materials and will expand her efforts to material for the upper levels of high school physics. She has seen the difference of approach for assignments for lower levels of high school (her own class) compared with upper level assignments (other participants’ experiences) during the programme and is aware of the possibilities this offers her in designing. She has now developed a strategy for design, where she would make a spider web of concepts and interesting sources around the context she chooses (source: post-course interview). In her final logbook she indicated that formulating the assignments is a continuing point of learning.

7.5.3 Teacher D

Teacher D had been wanting to try context-based education for biology since the start of the innovation process, back in 2005. She could never convince her colleagues this was worth while doing. The programme provided her with an opportunity to ‘show’ her colleagues this kind of education works (source: pre-course interview), although for her the programme was situated in a location three hours travel away. She therefore did not manage to visit all meetings from beginning to end.

She had a good idea on what context-based education should entail for biology, but not in general terms.

“Well, they [the contexts] used to be vague, like ‘the environment’, ‘biotechnology’, ‘health’, and ‘agriculture’. Now they are more defined, more the occupational perspective. [...] It is up to teacher to keep the three-partite of start-context, practise-context and test-context in mind (source: pre-course interview).”

She learned how context-based education is viewed in other science subjects and was able to provide a more general definition of what the context-based approach entails.

“A context is a story around the concepts, to give more coherence between and meaning to the concepts. You can keep the context close to the students, a societal context like cooking. It
Table 7.8: Description of the context-based competence change in teacher D

<table>
<thead>
<tr>
<th>Competency</th>
<th>Description of change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Context handling</td>
<td>Cognitive change on context definition and possibilities; insight in context-concept coherence; small change in classroom behaviour according to students.</td>
</tr>
<tr>
<td>Regulation</td>
<td>Cognitively this teaching concept has become more meaningful; success of this kind of teaching motivates her; significant change in behaviour according to students.</td>
</tr>
<tr>
<td>Emphasis</td>
<td>Significant cognitive change towards STS/KDS teaching; high score on emphasis compared to the general Dutch opinion*; significant behavioural change according to students.</td>
</tr>
<tr>
<td>Design</td>
<td>Finding a suitable context is most important; design incorporated student opinions and experiences to be used in the test and in next year’s version of the material; intention to design another project this school year.</td>
</tr>
<tr>
<td>School innovation</td>
<td>Incorporated contact with experts outside school because these are important for students; willing to provide feedback on materials from other participants in future.</td>
</tr>
</tbody>
</table>

* Compared to data taken from De Putter-Smits et al. (2011)

is not necessary to just stick to scientific contexts, because you often end up with the occupational perspective (source: post-course interview).”

She formulated the assignments for the students as small (literature) research problems. The material she designed for public understanding of science is made in such a way that it is open to change, either by additions from the students or herself (source: transcript from video 3rd meeting). This means that the next time she uses the material it will be different in both assignments and content and the results can be different every year. She uses a design strategy here that involves students in both their own test questions and in the context, allowing them to follow their own interest. The
new version of her material will be even more openly formulated (source: post-course interview).
She intends to start a context-based study module with a colleague for biology, with the experience she now has. “I wasn’t a beginner, but now I know how context-based education works” (source: post-course interview).

### 7.5.4 Teacher E

**Table 7.9: Description of the context-based competence change in teacher E**

<table>
<thead>
<tr>
<th>Competency</th>
<th>Description of change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Context handling</td>
<td>Cognitive change on context definition.</td>
</tr>
<tr>
<td>Regulation</td>
<td>Cognitively aware of necessary change in regulation.</td>
</tr>
<tr>
<td>Emphasis</td>
<td>Small change in the cognitive dimension towards KDS teaching.</td>
</tr>
<tr>
<td>Design</td>
<td>Change in design strategy is to start from the context rather than from last year’s material.</td>
</tr>
<tr>
<td>School innovation</td>
<td>No change in collaboration; official collaboration is hindered by time constraints.</td>
</tr>
</tbody>
</table>

Teacher E did not join the programme voluntary. She argued that since everyone else was going she would tag along (source: pre- and post-course interview). Teacher E considered the innovation was more to do with “recent events, newspaper stories and so on”. The students needed, in her opinion, to be able to reason logically rather than learning factual knowledge (by heart) (source: pre-course interview).

From the first meeting onwards she changed her view in accordance to what was taught. As she put it: “once I get, I get it you see. It makes sense to me and then I know it” (source: transcript from video 2nd meeting).

“Context-based education means you let students work in a context, which can be anything really. The students are provided with a ’script’ and a ’role’ to play. The script contains the assignment and the sources of information. The students decide how to tackle the assignment and the teacher decides the details of the final product. After the process students have learned certain [scientific] concepts (source: 1st logbook).”
She struggled to find a context that would be suitable to the first-year of secondary education students she intended to make material for. During the second meeting she had developed the ‘role’ her students would play in the context she chose (medication for heartburn) and was planning to share this class with teacher C that had quit the programme. However when she was about to start the classes, teacher C quit the school and the replacement teacher did not feel comfortable with the class swap. The project was thus cancelled.

Teacher E showed skill in using the principles of context-based education during the meetings. She inquired after the regulation in the ideas of others and helped them to find a suitable active form of learning (source: transcript from video 2nd meeting).

She indicated on the story-line graph she drew, that for her seeing the videos of the other participants helped her to picture the theory in practice much better. She is anxious to try her idea out next school year, to see “how it works out” (source: post-course interview).

### 7.5.5 Teacher F

Teacher F had experience in teaching context-based chemistry materials, since the school she works at is involved in the official pilot of the innovative materials for chemistry including the state exams. She was disappointed with the official material they were given (at school): “Those children have no freedom at all; they just have to do exactly what is said in the booklet. And the contexts, yes, well, sometimes I am rather disappointed in them.”

When asked about the context-based chemistry innovation she said:

> “I was rather disappointed by the official innovative contexts, I thought they would introduce new ones, but they seem to have reversed the order: applications first then the concepts leading to them. I guess I had hoped for new socks, but instead they turned the old ones inside out. Many contexts do not refer to society. The concepts, you could now go deeper into them. And of course you have to make them transferable [to other contexts] (source: pre-course interview).”

After the programme she was able to see the possibilities and necessities that arise from context use, but she was not able to generalise away from her subject chemistry.

> “I guess you can choose any context really, the students will be interested if you position it right. A context is a realistic
Table 7.10: Description of the context-based competence change in teacher F

<table>
<thead>
<tr>
<th>Competency</th>
<th>Description of change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Context handling</td>
<td>Cognitive change on possible contexts; clear view on restrictions from the official curriculum; small change in classroom behaviour.</td>
</tr>
<tr>
<td>Regulation</td>
<td>Cognitive change in allowing shared control over learning process; uncertain about this regulation concept; motivated by success of teaching; small behavioural change according to students.</td>
</tr>
<tr>
<td>Emphasis</td>
<td>During execution of context-based classes more FS; general emphasis no change; small behavioural change towards STS/KDS teaching according to students.</td>
</tr>
<tr>
<td>Design</td>
<td>Design starts from the context; her own model for designing context-based materials is: students first scout the context, learn theory in this context, translating concepts to a professional practice (authentic context).</td>
</tr>
<tr>
<td>School innovation</td>
<td>Collaboration makes the design process easier; contemplated introducing people from the authentic practice.</td>
</tr>
</tbody>
</table>

situation, such that the concepts ‘come to life’. (source: post-course interview).”

Teacher F had carefully formulated the assignment she presented during the second meeting, leaving not much for the students to discover. She was hesitant in reformulating it, since the students might not understand what they would have to do (source: transcript from video 2nd meeting). As she put it: “I didn’t dare to do it, but I did it anyway. And it worked (source: post-course interview).” Her conclusion on teaching the context-based materials showed she had realised what shared-regulation entails:

“The assignment can take students down different paths, but the risk you run is that the students get away with just [superficial] chatter, [rather than going deeper into it]. […] The teacher has less control over the learning process, but you have control over
the final product. I dare to let go more, now (source: post-course interview).”

This change is visible from the way first assignment was formulated to the final one she used in class. She mentioned she had once or twice wanted to take control and show her students what kind of calculation was expected of them (source: post-course interview).

Teacher F has a rather more KDS and STS oriented score for her general emphasis opinion compared to the general Dutch opinion (source: pre- and post emphasis questionnaire).

Teacher F is a very busy teacher and the school was not inclined to have her ‘skip classes’ for the teacher professional development programme. This meant she was unable to follow all the meetings from beginning to end and had to skip the 3rd meeting altogether.

7.5.6 About the programme

During the first meeting numerous questions arose on context-based testing. All participants agreed a standard test on the subject after the context-based classes would be inappropriate (source: transcript from video 1st meeting). Assignments designed by the participants included students’ reports, designs (drawings and calculations) and class presentations. The participants required information on how to mark these kinds of tests. The markings were in some cases done by the teacher using a rubric, in some cases by student and teacher markings of presentations and combinations of rubrics and classic tests (source: transcript from video 3rd meeting). In future programmes detailed attention on this part of the design is necessary.

Discussions arose during the final meeting on how to design material for different year-levels (grades 7-9 and non-pre-university tracks), for students with special needs (learning and behavioural disorders), and for students with and without science in their final exam. It was apparent from the teachers’ discussions that the idea of context-based education would be appreciated differently by students with different backgrounds and should thus have a different design. Something the programme did not incorporate in its design.

From the logbooks (3rd logbook) and final interviews it became apparent that the model of Prins (2010) introduced during the first meeting was
not used. As one teacher put it: “the model blocks creativity”. The participants expressed a simpler model or a checklist of elements that should be present in context-based educational designs would be helpful.

One teacher also expressed regret the programme did not provide an overview per science subject of modules available and the concepts treated therein. This would facilitate the incorporation of existing context-based material in his classroom: “for instance these chapters of our standard book could be exchanged for such-and-such module from new chemistry” (source post-course interview).

The participants indicated that it was a waste that the community they had become was now ending. They all experienced being part of a community, although not always on a personal level. During the programme they found each others’ comments valuable. “The atmosphere was friendly. I felt free to discuss my mistakes”, “Nobody put another person down”, “We were all thinking along the same lines”. Some suggestions were made for keeping the design community they had become and planning more (shorter) meetings in the coming school year to continue the work and the feedback discussions (source: 3rd logbook and post-course interviews).

The ample room for feedback both from experts and from the other participants of the programme was highly valued, judging from both the input from logbooks (1st, 2nd and 3rd logbook) and the final interviews. It made the theory “come alive” and “practicable”. The fact that they had to watch their own video, seeing themselves teaching was much appreciated and commented on as a strong point of the programme. “I used to get comments from my students that I my talk can be confusing, and now I saw myself doing it. I really need to watch my line of reasoning and not digress to other topics when a student asks a question” (source: post-course interview).

The personal attention and feedback from the experts and the researcher was also appreciated. “I had never expected I would receive sources and tips from the expert and researchers on my designed context”, one teacher confessed (source: post-course interview).

7.6 Conclusions and discussion

The teachers have all changed in the different competencies, mostly in the cognitive dimension, some even visibly to their students judging from the
student questionnaires. The use and handling of contexts has changed the most (see Tables 7.6 to 7.10). The participants were more aware on how a context can be used for student learning.

Also the regulation competency has a notable change among the participants. It was a much debated subject during the meetings: how much responsibility do you give the students, and at the same time control that they achieve the learning goal of the project. This became clearer after the classes were actually taught: students performed well with the ‘role-playing’ assignments coached by their teacher.

Teaching emphasis had changed towards KDS and STS teaching for two of the participants. This might be because they are more focussed and aware of what using context-based material can do in class: the students were enthusiastic; the student products that resulted were good; the classes were more demanding for the teacher but more fun or perhaps a welcome change. Once teachers have seen it *can* work they are more open to allowing this kind of teaching.

The visible change in the design competency is expected being the purpose of the programme. All participants intend to design context-based materials more often, although the total amount of designed material is not changed. The design competency is also mentioned in the suggested additions to the programme: a simpler model and ways to differentiate in your materials between different students. Another addition here appears to be the design of tests that do justice to context-based education.

The school innovation competency has hardly changed in the participants, judging from Tables 7.6 to 7.10, but when you read through all the comments it is apparent that it is just that what caused teachers to learn: listening to each other, giving feedback, discussions, these were the most appreciated activities by the participants. To continue this fruitful collaboration time and involvement of the teachers is required. Something most teachers are not willing to spend, although the participants in this programme suggested to form a community and to meet more regularly. Successful projects involving study communities of teachers are often set-up within the own school to facilitate these kind of meetings. These do however require support from the school’s management and continuing interest from the teachers (Mitchell & Mitchell, 2005). Only one pair of teachers managed to visit each other’s classroom, resulting in one learning event.
The programme intended to teach a broad view on context-based education, unspecified per subject. The participants appreciated that although they had all expected to learn more on their subject specific context-based innovation.

The teachers indicated that an even broader view on context-based education was necessary. They felt the idea of context-based education would need tailoring towards student needs if you want it to be successful in lower grades (7-9) and in lower levels of education. Most research is however directed at higher levels of education (pre-university) and at older students (grades 10-12). Research efforts for younger students and lower levels of education are therefore necessary.

Feedback and reflection in a protected setting was according to the participants the right environment to be open to change. The combination of designing, feedback, reflecting, teaching and reflecting once more, was found to be profitable to teacher change.

Considering that the programme was designed with the principles for effective professional development of teachers at the heart (cf. Borko et al., 2010), it is satisfying to see these principles returned in the evaluation on the programme. Active learning and sustained opportunities to learn, the ‘teach as you preach’ principle, involving classroom practice are all ingredients mentioned by Borko et al. (2010). Future programmes should put even more effort in using these principles when setting-up and executing a professional development programme for teachers.
Chapter 8

General conclusions and discussion

8.1 Summary of problem statement and research questions

This thesis addressed consequences for teachers and teaching of the proposed context-based reform of the science curricula in Dutch secondary education. Context-based education in general, starts with presenting a context from which the concepts are developed on a need-to-know basis (cf. Bennett et al., 2007). This requires teachers to teach in a more constructivist way, i.e. to position the scientific concepts in contexts recognisable to students and to stimulate active learning of the students (Parchmann et al., 2006). In this thesis five teaching competences teachers need for context-based teaching have been identified from literature. They were named: context handling, regulation, emphasis, design, and school innovation (see chapter 2).

The context handling competence includes the ability to present the context in context-based curriculum material successfully to the students, to help the students arrive at scientific concepts when working in this context, and to help the students to apply these concepts in various other contexts. The regulation competence in context-based education entails the ability to realise shared or loose teacher control in the classroom. Students learn more actively in context-based education, which demands that the teacher takes up a more guiding role and reduces traditional delivery of content. The emphasis competence includes being able to teach using a “knowledge development in science” (KDS) emphasis, where students learn how scien-
Scientific knowledge is developed in socio-historic contexts, and/or a “science technology and society” (STS) emphasis, where students are expected to be able to communicate about and make decisions on subjects from society that have scientific aspects. These two teaching emphases are suited to the kind of deduction of scientific knowledge on a need-to-know basis required in context-based education.

The design competence entails the teacher’s ability to (re-) design context-based curriculum materials to the situation in the own classes and to the students’ individual needs.

The school innovation competence concerns the abilities to cooperate with teachers within the school or with people from outside school in introducing innovations to the classroom. Context-based education can be multidisciplinary and may require obtaining expertise from other subjects or from institutions outside school.

To gain more insight in both the teaching competences in demand in context-based education and the issue of training teachers in this kind of education, the context-based teaching competence of teachers who were involved in the design of context-based curriculum materials was studied. A number of influences on the development of teaching competence were discovered and this knowledge was used to train secondary school science teachers in designing and teaching context-based education.

The thesis dealt with the following research questions:

1. Is the composite instrument able to measure the identified context-based teacher competences of science teachers teaching context-based oriented science classes in a reliable and valid manner?

In chapters two, three, and four the first research question was answered by designing and testing a composite instrument for measuring context-based competences. In chapter two, 10 teachers and 162 students were involved; in chapters three and four, 213 teachers, and 88 teachers and 1559 students were involved respectively.

2. What are the context-based teaching competences of science teachers who have worked in design teams for context-based curriculum materials and can these competences be attributed to the design team work?

a. What are the differences in context-based competence of science teachers who designed for different science subjects?
b. What other (informal) learning do teachers who have worked in context-based curriculum design teams experience?

c. Which elements in context-based design teams positively influence the learning of context-based competence in participating science teachers?

In chapter 5 research question 2a. and 2b. were answered in a correlation study between teachers with and without context-based design experience from different science subjects (33 teachers and 1024 students).

3. What is the content of a successful teacher professional development programme aimed at acquiring context-based teaching competences?

a. Is there a change in the context-based teaching competences in participating teachers due to the programme designed?

b. Is this change on the cognitive and/or on the behavioural dimension?

c. What (content) elements in the programme can be adjusted to improve the change in competences?

Research question 2c. and 3 were answered in chapter six, where a design for a professional development programme was presented, based on literature and empirical research (25 teachers). In chapter seven the research questions 3a., 3b., and 3c. were answered in a case study with 5 teachers and 74 students.

In this chapter the general conclusions to the research questions are formulated, followed by a general reflection on the results. The implications of the results are discussed and suggestions for future research are made.

8.2 Results and general conclusions

The results in this thesis can be divided into three main areas: the identification, measurement, and influencing of the teaching competences needed to teach context-based education successfully.

8.2.1 Context-based competences

In the research presented in this thesis, the five theoretically expected context-based competences have been measured in context-based classrooms.
They appeared to correlate to teaching experience and design experience, and it has also been shown to be possible to influence them through a professional development programme. In addition, it was found that teachers experienced in context-based education recognised them. Together, this provides empirical support that the theoretically expected competences are valid, practicable context-based competences.

The first three competences, context-handling, regulation, and emphasis, directly concern the situation in the classroom. The professional development programme (chapter 7), designed to improve the five context-based teaching competences in science teachers, was able to realise an improvement for these three competences. This mainly concerned an improvement on the cognitive dimension, but also some improvement was observed on aspects of the behavioural dimension. In contrast to this, no definitive conclusions could be drawn on the improvement on the competences design and school innovation.

The design competence is important to context-based education. To assist teachers in acquiring this competence, detailed characteristics for a professional development programme aimed at designing context-based curriculum materials were derived from literature and empirical research in chapter six. Learning about the design of materials was reported among designers of context-based curriculum materials in chapter five. Teachers enjoy learning these design skills and find them useful as was presented in chapter seven.

The school innovation competence was not very visible among designers (chapter 5). Although some indicated they belonged to a network, they did not see cooperation as an issue for their context-based teaching. The designers saw the network as separate from their teaching job. The school innovation competence seems present, although unrecognised by the designers.

An addition to the five competences that were found in literature and consolidated in practice, competence in context-based testing has been identified from the empirical research in chapters five and seven. This competence can be viewed as either part of the regulation or the design competence.
8.2.2 The composite instrument for measuring context-based competences

A composite instrument has been designed that measures the theoretically expected context-based competences in a valid and reliable manner. These context-based competences were addressed on the affective, cognitive, and behavioural dimension (chapter 2). The instrument consists of both qualitative and quantitative data sources. It uses data from three perspectives on the context-based learning environment a teacher is able to create: a student perspective through use of a questionnaire (WCQ -chapter 2 and 4) to be completed by students, a researchers’ perspective through classroom observations and interpretation of teacher interviews, and the teacher’s self-perception through two questionnaires (WCQ and emphasis -chapter 2, 3, and 4) and (reflective) interviews. Data from these three perspectives within the instrument were triangulated to create the context-based competence scores.

The composite instrument (see Figure 8.2a) was validated in a pilot-study (chapter 2) by identifying correlating data per competence cell (e.g. the context-handling competence on the behavioural dimension). The remaining items per competence cell were treated as competence scales for which a general Cronbach’s alpha was calculated to be 0.84, indicating the instrument’s reliability (chapter 2, p. 30).

The ability to discriminate between different groups theoretically expected to have high or low competence (sensitivity) was tested by calculating scale scores for each of the participants. A higher score is indicative of higher context-based competence. These scores were then correlated with (increasing) teaching experience and design experience with the hypothesis that significant correlations would be found for teachers with more teaching and/or design experience. The hypothesis was confirmed, indicating the resulting instrument is able to discriminate in teaching competence among teachers with different characteristics. It was therefore suitable to use in further correlational and other empirical studies.

The WCQ (student and teacher) and emphasis (teacher) questionnaires in this study are based on questionnaires from international research literature (cf. Taylor et al., 1993; Dorman, 2003; Van Driel et al., 2005). Their validation was assumed and verified in pilots, and their ability to measure competence elements of the context-based learning environment was studied. For the WCQ questionnaire in the pilot-study Cronbach’s alpha’s
ranging from to 0.74 to 0.87 were obtained (n=162). In the consecutive nationwide study the validity of the selected scales was confirmed in the sense that these measure the expected construct (see chapter 4), as is expressed in Figure 8.1. In the nationwide study (n=1630) values of Cronbach’s alpha were found ranging from 0.82 to 0.85.

Figure 8.1: Scheme for the revised WCQ -taken from chapter four

The emphasis questionnaire was adapted from the one used by Van Driel et al. (2005). It was used in a nationwide study (n=213) to validate the rephrased items. A principal component analysis confirmed which items belonged in the three emphasis scales (FS, KDS, and STS). Resulting alpha values for these scales ranged from 0.73 to 0.90.

A conclusion of the pilot-study was to combine two of the three competence dimensions addressed in the composite instrument, the affective and cognitive dimension, since it was found to be difficult to discriminate between these two. For the design and school innovation competences on the behavioural dimension no satisfying measurement was obtained, since only one data source provided information. It was decided to continue using only the validated scales.

From the various pilots it was concluded that the quality of the instrument was satisfying and that it would allow for measuring the context-based competences adequately. The resulting composite instrument (see Figure 8.2b) was used in the designer study in chapter five and the case study in chapter seven. The Cronbach’s alpha for the five competence scales on
the cognitive and behavioural dimension ranged from 0.50 to 0.91. Item rest correlations, relating the five competence scores to their mean (the total competence score) indicated that the first four competences are related (> 0.40).

The instrument was also used in evaluating the effect of a teacher professional development programme in chapter seven, using a pre-post measurement setting.

8.2.3 Factors that influence context-based competence

Context-based competence was found to be influenced by design of curriculum materials, the science subject that is being taught, and the use of curriculum materials.

8.2.3.1 Design influence

A main influence on context-based competence is being involved in the design of curriculum materials. In chapters four and five the results revealed that the design of context-based curriculum materials correlates significantly with context-based competency scores; teachers involved in designing curriculum materials appeared to show higher context-based competency scores with medium to large effect sizes (chapter 5). In the nationwide WCQ study (chapter 4) the student scores on the experienced context handling, regulation and the total context-based score were significantly higher for teachers who designed occasional materials for their classes or had been (regular) textbook authors (small effect size). In the research on the design of a professional development programme (chapter 6) strong indications from
literature and an empirical study among teachers with design experience were found, suggesting that a well-fostered design of curriculum materials by teachers is a successful learning environment for context-based teaching. This was confirmed in the case study in chapter seven.

Factors of designing curriculum materials that influence context-based competences were derived both from empirical studies and from literature.

One of the factors from the empirical studies was the number of teachers involved in the design team. Biology designers in chapter five had acquired the most context-based competence, however they were often working alone. Their hands-on experience with context-based education in making curriculum modules for their own classrooms, trying them, evaluating them, and redesigning them, made them familiar with this approach. In the study in chapter six, a higher number of teachers in design teams was found to correlate with low context-based competence. It could be concluded that the number of teachers in design teams should be carefully considered.

Another factor from the empirical studies was the expressed wish for feedback by the biology designers, since they did not have this opportunity. It was included in the set-up for the teacher professional development programme, where it was most appreciated (chapter 7) in combination with the input from experts.

The use of the material designed was also found to be an influencing factor in the empirical studies, as a form of active learning by the teacher (chapter 6).

The factor of forming a community was found for chemistry designers in chapter five. This was also a goal for the teacher professional development programme (chapter 7), however the participants said they would not continue unless they were supported by the researchers, mainly due to the factor time.

The main factor from the empirical studies was time. The drawback of the design of curriculum materials as a means for learning is the amount of time that is involved on top of time set aside for teaching. Besides teaching, teachers need to prepare their classes, make tests and assignments including experiments, correct homework and tests, attend various meetings at
school and so on. Designing curriculum material is not included in the class preparation time in most Dutch schools. The main part of the teachers’ task is teaching classes and in the remaining time all other teaching activities must be done. All teachers in this study mention that designing curriculum material is a (self-appointed) task that comes on top of all other tasks and thus takes up the teachers’ own spare time. This was mentioned by the teachers in the pilot study in chapter two, by the designers in chapter five and during the teacher professional development programme by the participants (chapter seven). Although designing proper curriculum material takes time, most teachers enjoy doing it, since its effect is visible in their classrooms (more enthusiastic students, experiencing at first hand how the material makes the students act\(^2\)).

From literature, key ingredients identified for teacher professional development programmes were: design curriculum materials coached by experts, having feedback and reflection opportunities with peers, the opportunity to use the material in class, using a structure to work by, and sufficient time to achieve all this. In a recent review of empirical literature, Voogt et al. (2011) identify similar factors important for teacher design teams from nine studies, some of which are a part of the theoretical basis of this thesis.

### 8.2.3.2 Science subject influence

Science subject seems to influence context-based competence. Dutch biology and chemistry classrooms score high on context-handling, regulation and emphasis. It could be suggested that the traditions of the subject or previous innovations towards context-based education has their effect on the teaching competence of the teachers.

Differences in context-based competences were also found for designers of different science subjects. These differences could be related not only the subject’s tradition, but also to factors in the design team set-up, as reported in the previous section. Biology designers were found to have the highest context-based competence, followed by chemistry designers, whereas physics and ASMaT designers did not acquire context-based competence (chapter five).

In the nationwide studies in chapters three and four, chemistry teachers and their classes score significantly higher on the WCQ and emphasis

\(^2\text{Note: teacher remarks from results in chapter seven}\)
questionnaires on the context-based competences context handling, regulation and emphasis. It could be suggested that the context-based innovation process secondary school chemistry in the Netherlands has undertaken since 2001, but that has its roots in the curriculum innovation of the seventies and early eighties (Hondebrink, 1987), has had its desired effect in the classrooms.

From the results of the WCQ questionnaire (chapter 4) it was found that chemistry students experience more constructivist learning environments in their classes than students from other subjects. In the sample in chapter three, chemistry teachers prefer a STS or KDS emphasis to FS, which is a change from the early noughties when FS was found to be predominant (Van Driel et al., 2008).

The context-based teaching competence context-handling is significantly less experienced by students of the new subject ASMaT\(^3\) than by students of other subjects (chapter 4). The ASMaT teachers however differ significantly from their students in their opinion on this competence, in the sense that they experience more context handling. The regulation ASMaT students experience is rather more shared than other science subjects (chapter 4), something the teachers concur with. The emphasis competence of ASMaT learning environments experienced by students was less compared to chemistry environments. However, ASMaT teachers had a significant preference for an FS teaching emphasis (unpublished result from chapter 3). It seems ASMaT teachers recognise the necessity for context-handling and regulation, but do not seem to effect the context handling competence in their classrooms. Their preference for FS teaching could be caused by feeling uncomfortable teaching advanced scientific concepts they have not encountered before, similar to inexperienced teachers for whom the patterns in their domain of experience have not yet become meaningful (Berliner, 2001).

The physics teachers in the sample prefer a KDS emphasis (chapter 3). Physics students do not concur with this finding, since no significant result is obtained for the emphasis learning environment scale in chapter four. Biology teachers and students experience an STS learning environment with shared regulation. It can however be argued that in the Netherlands biology as a subject is more prone to use such an emphasis due to its nature to explain concepts within the context they occur. For instance zooming in on the human body from the outward functions of respiration to the exact

\(^3\)Now known internationally as nature, life, and technology, NLT.
process of oxygen transfer in the alveoli.

### 8.2.3.3 Influence of curriculum materials

From chapters four and six it can be concluded that the use of context-based materials in science classrooms is a prerequisite for creating a context-based learning environment. However, more evidence was found for the use of a combination of context-based materials and a standard textbook as a prerequisite for creating a context-based learning environment.

The use of a standard textbook in combination with context-based materials is more strongly correlated to effecting a context-based learning environment than either the use of context-based materials only or the use of a standard textbook (chapter 4 and unpublished result of chapter 5). All five biology designers, that were as a group more competent in context-based teaching, indicated they used a (online) source book (concepts) so that their students have something to fall back on when working their way through the context-based curriculum modules. This combination of context-based assignments and a concept textbook is not common in Dutch context-based curricula, although it is the foundation of Salters’ chemistry in the UK and used (in a different form) in the CHiK teaching method in Germany.

### 8.3 Reflection and implications

The above results and general conclusions lead to a reflection and a discussion of implications of the method used in this research, the context-based competences, and the theory on teacher professional development. An outline of implications for the educational practice, teacher educators, and educational innovations is discussed subsequently.

#### 8.3.1 Reflection and implication on methodology

The methodological approach in this thesis has some restrictions due to the in vivo circumstances.

The measurements of context-based competence that were carried out in this thesis are situated measurements of competences shown in practice. Situation can exist where the teacher is unable to practice or show context-based competence. For instance: a teacher restricted to the choice of pedagogy his school makes, will comply and has to manoeuvre within
this situation. The instrument is not suited to measure a teacher’s ability or potential, it only measures context-based competence that is shown in practice at a particular time.

The study in chapter five and six on the teacher learning in design teams was done in retrospect, due to the time constraints of the PhD-research project. During the study, most design teams had ended their design project. This might influence the outcomes on the reported circumstances in teacher design teams and the reflections of the teachers on the learning that took place during their design experience. Conclusions on which factors influence their learning most, are therefore less reliable. To correct for this influence when using these data, the professional development programme (chapters 6 and 7) was also based on literature on successful teacher professional development.

The measurement of context-based competence, as shown in class, does not suffer from the retrospect constraint, since we only included active teachers in the study. To resolve the retrospective constraint, the learning and circumstances of teachers in the design group were monitored using the composite instrument in the case-study in chapter seven.

In the research described in this thesis 1795 students and 326 teachers participated. The research as such is subject to limitations such as participant illness, participants quitting the study, and incomplete questionnaires.

The samples in chapters two, three, four, and six were found to adequately represent the population.

In chapter five, the sample of designers aggregated over all science subjects was large enough (n=25) to use statistical tests. The samples per science subject are much smaller, making statistical testing inappropriate. However, the sample of biology and physics designers is large compared to the population of teachers designing for these subjects. Hence statistical testing plays a minor role in drawing conclusions, and the conclusions for these subjects are generalisable to the population. The samples of chemistry and ASMaT designers are small compared to the population, hence the results are dependent on statistical testing. Due to the small absolute size of the samples, making it vulnerable to individual deviations from the central tendency, conclusions are deemed to be indicative.
In chapter seven, three of the five participants were from a Steiner-Waldorf school that is uncommon (15 schools of the 1133) in the Netherlands. The teaching beliefs of these teachers are different from traditional schools in that they focus on the learning abilities of the individual and base all teaching on the theory presented by Steiner. It can be argued that such a view of learning when shared by the teachers facilitates change in teaching in those teachers. However, no indications of such effortless change were found in the study, hence the results are deemed indicative of general teacher change.

8.3.2 Reflection and implication on the context-based competences

The results and general conclusions in this thesis give rise to some annotations on the competences emphasis, design, and school innovation.

According to Van Driel et al. (2005) curriculum emphasis is situated in the beliefs domain of teachers. Beliefs have been found not to change even when it is logical or necessary for them to do so. The classroom behaviour a teacher shows however, is influenced not only by the teacher’s beliefs but also by previous experience (Pajares, 1992). Van Driel et al. (2005) found that about three quarters of their respondents have elements of more than one emphasis related belief system. This concurs with our findings that participants indicated that although they might favour one of the three curriculum emphases, they would also use another when the situation called for it. Another confirmation of more than one emphasis belief system was the shift in emphasis towards KDS found in teachers in chapter seven; in six months and three official meetings the shift was effected and even found in the classroom (student perspective). This is an indication that teachers are able to switch emphasis -within margins- as they are required, rather than preferring just one. It also indicates that teachers feel the need to switch to a KDS emphasis for teaching context-based classes, confirming the theory that a KDS or STS emphasis is fitting for teaching context-based education.

The design teacher competence is a practical competence, and plays a part in the preparatory phase of teaching. In context-based education, on the spot classroom design might be necessary depending on students’ questions, but the main part will be in a different phase in the teaching process. This competence requires a teacher to not solely rely on the curriculum materials given, to be confident to create own materials, and to know how
to design these materials in such a way that they achieve student learning. More and more, teacher design teams are formed to teach (in-service) teachers certain curriculum approaches (context-based education, maths literacy, religious moral education etc.) (Voogt et al., 2011). Therefore, it can be expected that general teacher competence, as detailed in for instance SBL: Stichting beroepskwaliteit leraren en ander onderwijspersoneel [Association for the Professional Qualities of Teachers] (2004) and European Commission Directorate-General for Education and Culture (2008), will include the curriculum design competence in the near future. Although this implies that this competence will no longer be specific for context-based education, it will remain much in demand in context-based education, since (re-) design of curriculum materials is often required.

The school innovation competence happens away from the classroom altogether. It entails interaction with teachers’ peers outside or inside school and on various levels. It has more to do with teachers’ openness to new and different subjects and their interest to aid and be aided by others in their work: teacher professional growth. The teaching practice where teachers are ‘king’ of their classrooms is becoming a thing of the past. For context-based education this competence is necessary to ensure cooperation with the different science subjects and with representatives from the contexts used in class. Hence, context-based education relies on teacher interaction with peers and others (see chapter 2).

For the designers in our study it would seem they do not see the link between their outside school activities and their teaching, considering their additional jobs and their low score on this competence (chapter 5, p. 97 and p. 99). In literature, communities of teachers are successful when they have a common goal. For instance, as a starting point for discussing results of teaching, teachers have a mutually held understanding of what types of classroom practices nurture learning (Erickson, Brandes, Mitchell, & Mitchell, 2005). This common goal was probably lacking in the cooperation of the designers with colleagues and others: the goal of the designers was to create context-based curriculum materials for their own classes, which was not the goal of their outside school activities. When the designer’s goal was matched with the outside school activity (both on astronomy) the designer did see an increase in network related to teaching context-based materials (teacher B from chapter 7).

The five competences uncovered in this thesis may not be a complete
set of teaching competences needed for context-based education. Though established in this thesis, they are also a starting point for uncovering other possible teaching competences that are specific to or more in demand in context-based education. Also more detail on the competences found may be uncovered. An example of the latter, is that of the nature of the actual teaching activities under shared regulation. The teaching activity ‘performing an experiment’ in context-based education should lead the student to a discovery that is needed to explain a concept or further the student’s investigation into the context at hand. In traditional education experiments serve to underline a concept already learned.

An addition to the competences that were established in this thesis is context-based testing. Testing is according to Roelofs et al. (2008) one of the five areas of teacher competence. Testing can be connected to both the regulation and the design competence. In context-based education, shared or loose regulation is called for, which results in a change in testing students on acquired knowledge and skills. Vermunt and Verloop (1999) provide some details on possible ways that teachers can aim for students to help each other become competent. Context-based testing should also be a part of the design competence as it is an essential change away from normal test design. So far however, only one publication on how to design context-based tests is available (Nentwig et al., 2004).

Secondary school teaching in the Netherlands is under pressure. More and more emphasis is put on the individual learner, requiring the teacher to differentiate the lessons. Also the tendency for students not interested in sciences to take a science class and the obligatory public understanding of science\footnote{Dutch: algemene natuurwetenschappen, ANW} in high school demands a different approach. Besides these developments, special needs children are more and more expected to attend standard high schools. Together this puts an additional demand on the teacher when implementing context-based education. For instance: students not interested in science will not make the effort to do in depth situated calculations and students with autistic disorder need very clear instructions and preferably a logical concept-based textbook that are not usually a part of Dutch context-based curriculum materials. These individual differences of students put even more demand on the (re-) design competence of the teachers to include know-how to adapt context-based materials to every learner’s need.
8.3.3 Reflection and implication on the theory of teacher professional development

In the research presented in chapter five, ASMaT designers scored significantly lower on context-based competence than their colleagues. It has been argued that competence is manifested in performance in a specific situation (Spencer & Spencer, 1993), however then the situation should be able to occur, which in the case of the ASMaT designers in the study presented in this thesis, did not happen. They never taught the context-based curriculum materials they made, nor any other context-based material. The theory that designing curriculum material is beneficial to learning to teach the material is thus not disproved by the sample of ASMaT designers in the study.

Active learning in empirical professional development studies is usually some kind of hands-on activity, such as teachers studying student mathematical problem solving together (Borko, 2004) or evaluating disappointing student learning after teaching successful lessons (Mitchell & Mitchell, 2005). In our interpretation of the theory of successful teacher professional development, the characteristic active learning was represented by teaching using context-based curriculum materials. Our findings indicate that our interpretation was valid, in the sense that there is a positive influence of context-based material use on the context-based competences of teachers. The teaching of a certain kind material can be added to the hands-on activities as a valuable means to learning a certain pedagogical approach, as is also advocated by Voogt et al. (2011).

Having teachers design context-based materials has the advantage that the teachers not only learn more about context-based education. It also provides teachers with insight into how curriculum materials are made, which could benefit them when using other people’s curriculum materials. Since they know how exercises and experiments are meant to address concepts they appreciate material made by others more (chapter 5, p. 103). Hence, it can be expected they will be able to match their teaching style to the materials’ intention more easily. Teachers aware of the intentions of context-based curriculum materials in general were found to be able to teach a new context-based curriculum module successfully (Vos, 2010). Design experience would give a teacher this awareness, and would thus aid successful implementation of the context-based innovation.
The committee for ASMaT has provided guidelines for the curriculum modules that include engaging student activities, which are visible in practice (chapter 4). They also advertised the subject as having more in depth science concepts and calculations, which might incline teachers uncertain about these new concepts to teach them strictly according to a textbook. Teachers are not comfortable with the more difficult concepts, that can be from a subject alien to them, to be able to connect well to the context and to chose a different teaching emphasis. ASMaT teachers have not had a training programme to teach the subject although research into this is ongoing (cf. Visser et al., in press). In such a programme attention should be paid to the context-based competences, specifically the context-handling, emphasis and regulation competence.

8.3.4 Implications for the educational practice, teacher educators, and educational innovations

8.3.4.1 Implications for the educational practice

This thesis has contributed to making clear which context-based teaching competences are important from a coupled theoretical and practical perspective. The educational practitioners can use the five context-based competences to reflect on their own teaching practice. Teachers starting context-based education can use the five competences to help visualise the change in teaching practice necessary. A prerequisite for both these implications is however, that a translation is made from the academic style thesis to a practical teacher document.

In general, when embarking on a new educational approach such as context-based education, teachers and school leaders should consider the design of such instructional material by teachers as a means to successfully introduce the new approach. Teachers should not only design the material, but also use the material in their own classrooms to experience the change in learning and teaching context-based education requires. According to theory on successful teacher professional development it is essential this kind of learning is a team activity (cf. Borko et al., 2010). Peers provide one another with support, feedback, and reflection. Experts can guide and support the professional development of the teachers. Finally, sufficient time should be reserved for implementing a new educational concept; the standard lesson preparation time is too little time to prepare a teacher for a change in the teaching practice.
From observing teachers at work with context-based material, the question can be put what the effect of context-based materials are on students when teachers do not pay any attention to the context, shared regulation, emphasis and so on. It can be argued on the one hand that the material will be unsuccessful in attaining its goal in being more motivating for students, similar to the friction Vermunt and Verloop (1999) describe for the kinds of learning activities students and teachers prefer. On the other hand it can be argued that students will perform learning activities of their own desire, regardless of teacher interference as is suggested by Shuell (1996). Besides teacher influence, the curriculum material itself can be clear in its intentions, and guide the students through the learning activities regardless. Depending on which of these two theories on student behaviour is found in practice, the need for teacher professional development will be different.

In the first case, it is of foremost importance to make teachers aware of the differences in teaching that are necessary for context-based education. On implementation of a context-based curriculum nationwide teacher professional development programmes need to be offered to ensure the innovation is successful.

In the second case it is the context-based materials that need the most attention. They should be fully self-explanatory with the elements of context-based education (context handling, regulation, emphasis, design and school innovation) translated to the textbooks, worksheets and teacher handbooks.

The use of context-based materials was found to be a prerequisite for creating a context-based learning environment. This concurs with the results for context-based chemistry found in the case study by Coenders et al. (2008). However, combining this with the hazard of the possible friction between teachers using a regular teaching strategy and the desired context-based approach (first case), it is still the teacher who determines how context-based the learning environment will be. When given the opportunity to use context-based materials, the teacher then requires the skills, including design skills, and the determination to use it.

8.3.4.2 Implications for teacher education

Innovations in education should find their way into regular teacher education as soon as possible. Therefore, also context-based education should be addressed in science teacher education. Innovative curriculum materials are now freely available to teachers and it is expected that the context-based
curricula will be approved by the Ministry of Education, Culture, and Science in the near future. Besides these developments the context-based approach has a merit of its own and should be a part of teachers’ pedagogical content knowledge. “The special amalgam between content and pedagogy” (L. S. Shulman, 1987, p. 8) for context-based education consists of the way contexts can be used to arrive at scientific concepts and the pedagogy (the five context-based competences) involved to achieve that goal.

As a basis for teacher training the five context-based competences could be used and special attention could be paid to context-based testing methods. The ingredients suggested in the previous section (8.3.4.1) for a successfully introducing a new educational approach are valuable to teacher trainers interested in preparing context-based teacher training programmes.

From the research presented in this thesis it would seem prudent to provide ASMaT teachers with professional development programmes, not only aimed at acquiring content knowledge on specific topics addressed in the different curriculum modules, but also to the change in teaching context-based materials require.

Biology teachers would probably benefit from the suggested teacher professional development, in designing and teaching the new materials in teams of peers.

Chemistry teachers have to deals with the complicating factor of different learning continuity pathways to choose from. For them the suggested teacher professional development, in selecting, designing and teaching the new materials in teams of peers is important, possibly with the aid of an expert in the different learning continuity pathways.

According to evaluation studies, teacher professional development is necessary to enable physics teachers to use the context-based physics materials (Bruning, Folmer, Ottevanger, & Kuiper, 2011). In this evaluation study teachers had little time to (re-)design the materials to their needs, or design their own materials. For this kind of teacher professional development the key factors found in this thesis can be used.

The general curriculum design competence should receive more attention in teacher education. Not only in view of the current context-based innovation in the science subjects, but also in view of the powerful tool designing curriculum materials is for discovering how students learn and how to influence this learning (this thesis chapter 7, p. 151 and Deketelaere and Kelchtermans (1996)). The learning of students is one of the teachers’ main
interests and thus designing curriculum materials should not be lacking in teacher education.

**Tools** The instruments developed and used in this thesis are tools that can aid teachers and teacher educators to monitor classes and changes in teaching. The questionnaires are freely available through the research facility CORF (www.corfstart.nl).

The WCQ-questionnaire is a tool teachers could use to map the context-based learning environment they are able to create and to reflect on the outcome. This questionnaire should then be made available to the teaching practice, including bench mark scores.

**8.3.4.3 Implications for educational innovations**

The research presented in this thesis uncovered that using a mixed-method in curriculum material, that combines a concept-oriented textbook with context-based curriculum modules is related to effecting a context-based learning environment (results from chapter 4 and 5). Combining context-based modules with an encyclopedic textbook is the strategy chosen by both Salters’ chemistry (a context-based chemistry method in the UK) and Chemie im Kontext from Germany for their curriculum materials. In fact, they stress that this is key to their curriculum material. Should the context-based innovation in the Netherlands be implemented, curriculum materials developers should take this to heart and use a similar structure that has been proven to be as successful as regular curriculum materials (Bennett & Lubben, 2006).

The context-based innovation is expected to be implemented for the science subjects in the Netherlands in 2013. Before this date, a general support for the science teaching field should be developed, based on the key factors found in this thesis, preferably in schools. This could be initiated by institutions for teacher education or private networks that have the necessary expertise. In view of the school innovation competence however, a professional development programme should preferably concern a schools’ entire science department.

The current innovation seems to have a promising start for chemistry and biology. The general opinion of teachers in these two subjects is more towards context-based education than that of e.g. physics teachers. A more context-based curriculum carefully harboured by providing teachers with
the professional development necessary will be feasible in the near future.

Time for designing and professionalising is an important factor found in this thesis. However, that is something teachers and schools do not have enough of. From the results presented here it can be argued that the division of time between actual teaching and other school activities needs to be changed in order to enable schools to innovate effectively. Compared to other European countries the Netherlands provides its teachers with less time to prepare classes (average is 22 hours teaching in a 40 hours per week job, compared to 25 hours in the Netherlands; calculated from Ranguelov, De Coster, Forsthuber, Noorani, and Ruffio (2009)).

Top-down innovations tend not to be successful since they are generally not supported by the teaching field (Fullan, 1994). The Dutch innovation studied here used both a top-down and a bottom-up approach (cf. Driessen & Meinema, 2003). In this model each interested party is involved in the decision making, although the final decision is made by the Government, in this case the Ministry of Education, Culture, and Science. Piloting the curriculum in the year-levels the new curriculum meant the innovation was tried out and independent evaluation studies ensured that the innovation was evaluated before implementation. This strategy leaves room to improve the curriculum before the final implementation, avoiding start-up problems. This combined approach to innovate a curriculum should lead to a change in the curriculum that is generally supported, not only by academic experts, but also by the teaching field. Although it is too soon to tell whether this innovation as a whole will be successful, it is a promising model. Future innovations in education could use this model including the recommendations from this thesis regarding the role teachers can fulfill as designers and implementers of curriculum materials.

8.4 Further research

In this thesis, the focus was on the measurement of context-based competence among science teachers and their professional development towards context-based competence. The research presented yielded an instrument to measure the competences and insight in the development of competence in science teachers who designed context-based curriculum materials. Future research could feature the instrument, the competences, and the professional development of teachers.
The composite instrument as it is now (see Figure 8.2b) lacks indicators for design and school innovation on the behavioural dimension. To perfect the composite instrument, research could be carried out in designing and evaluating instrument parts that are indicative of these competences.

As mentioned before, context-based testing methods has not yet been the subject of in-depth research. Context-based education would benefit from research in this area, since it would provide the last piece of the educational approach. When this research is completed, the composite instrument developed in this thesis should be carefully adjusted to incorporate indicators for this competence.

The context-based competences distinguished in this thesis could be applied to study other educational fields, such as language studies and economics. This could lead to the discovery of more context-based competences and a broader description of competences involved in context-based education. These non-science context-based learning environments could possibly be studied using an (adapted version) of the composite instrument.

The teacher professional development programme that has now been put into practice once, could become the topic of a design research cycle such as Gravemeijer and Cobb (2006) propose. This would not only provide insight in the actual learning processes of designing science teachers, but would also lead to an optimised programme to professional development of teachers towards context-based education.

When the context-based innovation is implemented in the Netherland, nationwide research should be carried out on its effects, both in student grade results as in students motivation to choose science as a future education. The results from this research should be used as a basis for discussion on how to proceed with the innovation. In the past innovations were implemented in legislation without proper research, only to discover in the evaluation instigated by lack of success that the innovation should have been implemented differently (Ministerie van Onderwijs, Cultuur en Wetenschap [Ministry of Education, Culture and Science], 2005).
Epilogue

A personal reflection on the teacher-researcher experience

Doing a PhD research is demanding. Most people would agree that teaching high school physics is demanding. So what does a combination of the two demand of the performing artist? Teaching skills, research skills, project management skills, communication skills and perseverance would be my answer.

For four years I have combined teaching physics and a PhD-research project with the results you are reading now. As an external PhD candidate I have had the opportunity to work with professors and research staff of the university I was associated to as well as with staff of other universities. For me, the world of educational research has now become part of the high school teaching world and I see the possibilities of combining the two. In practice however, they are still a long way apart (Broekkamp & Van Hout-Wolters, 2005).

It is often cited that researchers have an idealised view of the classroom. Teachers have a tendency to take 'shortcuts' with research suggestions, undermining the effect the suggestions could have. I can view both perspectives and understand them. Yet, what is next for a recently PhD’ed physics teacher? Of the 20 people given the opportunity to do a PhD next to their teaching job in the framework of the DUDOC-programme funded by the Dutch Ministry of Education, Culture and Science, none so far has found a way of continuing bridging the gap, to convince both sides of the other’s advantages. The role we played as bridge-builders between the two worlds seems to end and no lasting bridge seems to have been built. Rather the bridge is being build anew, since other initiatives of PhD-research for
teachers have taken off. We were probably expected to cross over to the other side or go back to our own side, but our knowledge on how to cross-pollinate ideas from both worlds now remains unused.

The DUDOC-group expressed the wish to be given the opportunity to disseminate our findings to the teaching world. Funds for this kind of dissemination are few. As are funds for future teachers to do teacher research next to their teaching practice. However, if teachers are to be viewed as professionals opportunities to do research and not only in-service teacher training should be provided. Professionals make up their own minds on which route to take the goal of teaching the national curricula and are not dependent on the choices the Ministry of Education, Culture and Science.

Perhaps a solution is to try to keep the network the teacher-researchers have together alive. To formulate goals that include opening up educational research to the teaching world. Starting with our own project we could start a bridge between the two worlds and become the agency that provides professional development for teachers from research, that provides assistance for teachers wishing to research their own teaching practice. Which university or professional educational institute dares to pick up this glove and go into battle with us?
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Index

List of acronyms

ASMaT: Advanced Science Mathematics and Technology (Dutch: NLT)
biko: biologie im kontext
CBLE: Context-Based Learning Environment
CFI: Comparative Fit Index
ChiK: Chemie im Kontext
CLES: Constructivist Learning Environment Survey
CORF: Collectieve Online Research Faciliteit
DUDOC: Didactisch Universitair onderzoek door DOCenten
ESoE: Eindhoven School of Education
FS: Fundamental Science
HAVO: Hoger Algemeen Vormend Onderwijs
KDS: Knowledge Development in Science
KM-test: Kastle-Meyer test
KMO-test: Kaiser-Meyer-Olkin test
NLT: Natuur, Leven en Technologie
pca: principal component analysis
piko: physik im kontext
POVB: Platform Onderzoek Vernieuwing Bètavakken
QIB: Questionnaire on Interpersonal Behaviour
RMSEA: Root Mean Square Error of Approximation
SMRS: Standard root Mean Square Residual
SPSS: Statistical Package for the Social Sciences
STS: Science Technology and Society
TLI: Tucker Lewis Index
TPD: Teacher Professional Development
VWO: Voorbereidend Wetenschappelijk Onderwijs
WCQ: WIHIC, CLES and QIB
WIHIC: What Is Happening In this Classroom
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Appendix A

Interview format context-based education -pilot study

A.1 General

1. How old are you?

2. On which level did you complete your education?

3. In which subject did you graduate or take your PhD in? (biology, chemistry, physics, engineering, etc.)?

4. Which teaching qualification do you hold for the science subject you teach?

5. How long have you been teaching and which subject do you read?

6. Do you have any other jobs/tasks besides teaching (even outside school)?

7. Did you ever participate in writing instructional materials? (which one, when, how long for etc.)

A.2 Context-based education

8. Why did you start teaching a study-module from the (ASMaT / biology / chemistry / physics) innovation?
9. Did you have any experience with context-based education prior to the start of this module? If so: what kind?

10. According to you, what does context-based education entail? How can it be defined?
    - Method from contexts to concepts and back
    - Role of the student
    - Teacher role
    - Other:

11. Could you describe what the differences are between context-based education and the traditional way of teaching?
    - subjects / context
    - theoretical concepts
    - feeling of belonging to a group
    - team work
    - planning
    - other?

12. What is reconceptualising according to you? (explain if necessary)

13. Do you do this in your classes and if so can you give me an example?

14. What is recontextualising according to you? (explain if necessary)

15. Do you do this in your classes and if so can you give me an example?

16. How would you describe a successful context-based class, perhaps by giving an recent example?

17. Do your classes follow the context-based approach as you have indicated / defined earlier?

18. (If applicable) Could you describe the changes in your knowledge and skills in context-based education in this graph? (Ask about the causes of changes indicated in the graph)
A.3 Learning functions

19. Have you noticed differences in your approach to students since you teach this module? If so, what difference?

20. Have you noticed differences in students’ approach to you since you teach this module? If so, what difference?

21. Do you think your teaching in this class is different from the other classes you teach? If so, what is different?

22. Next, I will present three teaching strategies. Could you tell me which one you would prefer and why?
   
   Teacher A, B and C mean for their students to learn chemical equations.

   Teacher A requires the students to find out how much sulfite should be added to white wine to increase the use-by date, taking care not to exceed the legal health limits.
Teacher B provides a theoretical explanation on the blackboard and requires the students to complete exercises from their study book, practising the chemical equations.

Teacher C has the students do experiments, where the students learn the equations by doing, observing and creating.

23. Do you think your choice would have been different prior to teaching this module? If so, how different and why? If not, why?

A.4 (Re-)Design

24. Did you do a lot of preparation to teach this module? What kind of things were they?
   - (official) Preparatory meetings
   - Training
   - Observing in other schools
   - Organisational aspects
   - Reading the module / teacher notes
   - Discuss with colleagues
   - Search the Internet
   - Lesson preparation / experiment preparation

25. Were you able to use the module as provided or did you have to make changes to the module? Which and why?

26. When you compare the amount of preparatory work for this module with the work for a new text book, is there a difference?
   - Acquainting oneself
   - Adapting to school circumstances
   - Making schedules and exams/tests
   - Other preparations?

27. Should a colleague from another school (on a conference or something like that) ask you what it is like teaching this module and what kind of practical issues are involved, what would you say? Would you advise in favour or against the module, or ...?
28. Should a colleague from another school ask about this module, how would you describe the learning goals and the essence of the module?

A.5 Context-based education in school

29. Did you cooperate with colleagues of your own subject or of other subjects when you started with this module?

30. Did you cooperate with the principal or timetabler or . . . ?

31. Does any of these cooperations still continue?
   If so: what do you generally discuss?

32. Are there more colleagues in your school that use this module? (why / not?)

33. Do you interact with your colleagues in this school or another school about this module?
   • What kind of support do you offer each other?
   • Are any of your colleagues experienced in context-based education?

34. Do you cooperate with other schools for this module?
   If so: in what way?

35. Do you cooperate with institutions outside school (universities, companies) for this module?
   If so: with whom and what is the nature of the cooperation?

A.6 Final questions

36. Looking back on what you know now, would you use a context-based study module again?

37. Would your strategy change?

38. Would you like a transcript of this interview?

39. Could I ask for your cooperation for my research in the future?

40. Should you have any questions or remarks after this interview, please feel free to contact me via email.
Appendix B

Interview format after context-based class observation -pilot study

B.1 General

1. How do you feel the class went, are you satisfied?

2. Are there any incidents in the class that were out of the ordinary?

B.2 Preparation

1. How did you prepare for this class?
   - How much time did your preparations take?
   - Did you use separate material or sources, colleagues?
   - Did you design anything for this class? (experiments, schedule, booklets etc.)
   - Could I have a copy?

2. Does the preparation for this class, in general, differ from other classes that you teach?

B.3 Executing the class

If this was the first class of the series:
1. How did you introduce the series of classes?

2. If you would do this class again for another group of students, would you introduce the series differently?
   If this was a normal (context-based) class:

3. Did you treat any concepts today?
   If so (4 t/m 7); If not (9):

4. How are, or how did you introduce the concepts in this context?

5. Where your students familiar with these concepts?
   If so

6. How come?
   If not:

7. How did you treat / explain the concepts? (If necessary provide examples I have observed and ask about them)

8. Did you do this the same way you would in a normal class (not context-based)?
   If so: Why and how
   If not: Why and how

9. Did any specific contexts arise in this class? (e.g. scientific, societal, authentic etc.)
   If so (10 - 13; else 14 and 13):

10. Which and how?

11. Was this a logical context for you?

12. Were your students familiar with this context? Did they see or study this before?

13. In your opinion did your students experience the same context(s) as you did, or as the instructional material intended? Could you elaborate on that?

   If not: (if necessary bring up contexts I have observed)
14. I experienced this context. Is this a context to you? Is it a logical context to use?

15. Is teaching using these context-based modules different from how you normally teach?
   If so:

16. Can you describe the differences?
   If not:

17. Can you describe the similarities?

18. Can you indicate what in this class is typical for the context-based classes? Something that wouldn’t happen in your ordinary classes?

19. Is your role as a teacher in the context-base classes different from the one in ordinary classes?

20. Is the role of the students different in these context-based classes?

21. Were there any typical occurrences in this class that are typical for context-based education?

22. Were there any other things in this class that have to do with the innovation?

23. What do you think motivates students to learn? What do you do to motivate them? What is the role of the marks in this? Of the subject at hand? Of the . . . ?

B.4 Specific situations

I would like to recall some situations from the class and ask you why you handled them the way you did. This provides me with some insight into the 'bag of tricks' a teacher has.
B.5 Final questions

1. Did you reach the goals you had for this class? (content, what students should have learned, kept schedule)

2. If you taught this class again tomorrow, what would you change?

3. Are there any remarks /suggestions you would like to make about the class I observed, about context-based education or my research?

4. Could I return to observe another class?

5. Would you like me to send you a transcript of this interview, so you could add or change the content? If so, where can I send it to?

6. Could I approach you for a new research project at some other time?

7. Should there be anything you wish to contact me about, feel free to email me.

Thank you very much for you cooperation.
Appendix C

Interview format teachers with curriculum material design experience -pilot study

C.1 General

Background of the teachers

1. How old are you?

2. On which level did you complete your education?

3. In which subject did you graduate or take your PhD in? (biology, chemistry, physics, engineering, etc.)?

4. Which teaching qualification do you hold for the science subject you teach?

5. How long have you been teaching and which subject(s) do you read?

6. Do you still teach?

7. What kind of classes are they: context-based, regular etc.?

8. Do you have any other jobs/tasks besides teaching (even outside school)?

9. Did you ever participate in writing instructional materials? (for whom, which kind, when, how long for etc.)
C.2 Motivation

To compare with motivational reasons for successful teacher professional development: subject related, personal need, student learning, coincidence with other learning activities.

1. Why did you join the design team for . . . . . . . . (name of module)?

2. Did you have a personal goal when you started the team?

3. Were you compensated in time or money for your design team work?

4. Did that influence your choice to participate in the design team?

5. When you look back, what was the most influential reason to joining the design team? (recall from mentioned items)?

6. Did you work in the team from the start of the process up to the end?

C.3 Team

According to literature most learning occurs when teachers work with an expert on something directly involving their teaching practice (Garet, Fullan, Cochran-Smith e.a.). Other reasoning: if the team was unsuccessful, was it an ideal circumstance for learning in the first place?

1. When did you join the design team? Until when did the project run?

2. Who were in the design team? (background)

3. How often did you work together? (times per month, week, year)

4. Can you estimate for me, how many hours you personally have put into the project?

5. Were there any people involved in the project outside the design team? If so, who?

6. Did the design team have a division of tasks? Which?

7. How was the team managed?

8. How would you describe the team work: structured or chaotic, cooperative, many discussions etc.?
9. How would you describe your role in the team?

10. How would you describe your contribution to the module and the team work?

11. Do you think you will keep in contact with the other members of the design team after the project has finished? Why so or why not?

12. If you were given the opportunity of putting together your own design team, who would your (ideal) team members be? (which capacities, professions, teachers, experts, editors, writers etc?) Why?

C.4 Structure of the project

Confirming the ideas of Van Merriënboer and Plomp etc on instructional design models. Go into organisational aspects to look for ideas on the ideal learning environment and successful team work.

1. When you started the design project, were there any fixed features? Such as:

   • Organised process with a schedule or project planning (deadlines, minutes, reports, document structures)?

   • Instructional design model for writing the modules (or an experience-based model: ADDIE)?

   • A document with the content of the module, concepts, contexts, pedagogical approach, typographical format?

2. Who had organised these features?

3. Should you join a design team again, which of these features mentioned above would you like to see, or like to see changed?

C.5 Learning experiences

Confirming peer learning and informal learning in this (according to literature) ideal circumstances for learning. Direct questions on context-based education: context-and-concept, teacher regulation, emphasis, design and school innovation
1. What kind of information about the context-based (science subject applicable) innovation did you study or look at during the design process?
Where did you find this information?

2. Did you follow a course or training during your time in the design team?
If so: What was the training about and was it valuable to you as a designer? and as a teacher? Why?
If not: Would you say you lacked some kind of training? Why (not)?

3. How would you describe the core of the innovation for (science subject)?

4. What were most visited topics discussed in the design team? (pie-chart and asks for percentages)
   - How to deliver the context?
   - Concept transfer?
   - Concept training?
   - Experiments?
   - Students working in teams?
   - Open ended versus closed assignments?
   - Strong controlled versus shared controlled material?
   - Student role?
   - Teacher role?
   - Other matters of pedagogy.....?

5. Of these discussions, what topic do you remember strongly, what struck you, an 'eye-opener' to you as a teacher?
   And as a curriculum designer?

6. Was the curriculum module or parts thereof tried in class during the design process, a trial-run?
   If not: why?
   If so: How often, to which extent?
   Did you think that was valuable as a curriculum designer?
   And as a teacher?
   Did you visit the classroom of a colleague who was trying out this
material?
If not: why?
If so: was it valuable to you as a designer?
And as a teacher?

7. Next, I will present three teaching strategies. Could you tell me which one you would prefer and why?
Teacher A, B and C mean for their students to learn chemical equations.
Teacher A requires the students to find out how much sulfite should be added to white wine to increase the use-by date, taking care not to exceed the legal health limits.
Teacher B provides a theoretical explanation on the blackboard and requires the students to complete exercises from their study book, practising the chemical equations.
Teacher C has the students do experiments, where the students learn the equations by doing, observing and creating.

8. Do you think your choice would have been different prior to designing context-based study module(s)? If so how different and why? If not, why?

9. What was your attitude towards designing materials when you started your design team work (start storyline)?

  • Positive, reasonably positive, neutral, reasonably negative, negative?
  • Why?
  • Can you indicate how your attitude towards designing materials changed during the design process?
  • Inquire after curves, drawn etc.
  • You indicate that your attitude toward designing is now more (pos / neg /same). Why is that?
  • The trend you drew in the graph is for 25, 50, 75, 100 percent the result of your participation in the curriculum design team?
  • The trend you drew in the graph is for 25, 50, 75, 100 percent the result of activities and experiences outside the design team. They are: . . .
10. How would you describe your knowledge and skills in designing materials prior to your design team participation (start storyline)?

- Expert, intermediate, beginner?
- Why?
- Can you indicate how your knowledge and skills have changed during the design process?
- Inquire after curves, drawn etc.
- You indicate that you are now a (Expert / Intermediate /Beginner). Why?
- The trend you drew in the graph is for 25, 50, 75, 100 percent the result of your participation in the curriculum design team?
- The trend you drew in the graph is for 25, 50, 75, 100 percent the result of activities and experiences outside the design team. They are: ... 

11. Did you design materials for your own classes prior to your design team participation (start storyline)?

- Never, sometimes, regularly, often?
- Do you have a special reason for doing so?
- Can you indicate whether you have started to design more materials for your own teaching practice since you participated in the curriculum design team. (Examples?)
- Inquire after curves, drawn etc.
- You indicate that you now (never / sometimes / regularly / often) design materials for your classes. Why is that?
- The trend you drew in the graph is for 25, 50, 75, 100 percent the result of your participation in the curriculum design team?
- The trend you drew in the graph is for 25, 50, 75, 100 percent the result of activities and experiences outside the design team. They are: ... 

12. What was your attitude towards context-based education prior to your participation in the curriculum design team (start storyline)?

- reminder: scientific knowledge based on subjects from society, context delivery, concept transfer, concept training, activating teaching strategies, different teacher role, working with other science subjects?
• Positive, reasonably positive, neutral, reasonably negative, negative?
• Why?
• Can you indicate how your attitude toward context-based education changed during your participation in the design team?
• Inquire after curves, drawn etc.
• You indicate that you are now more (pos / neg / same) about context-based education. Why?
• The trend you drew in the graph is for 25, 50, 75, 100 percent the result of your participation in the curriculum design team?
• The trend you drew in the graph is for 25, 50, 75, 100 percent the result of activities and experiences outside the design team. They are: . . .

13. How would you describe your knowledge and skills in context-based education prior to your participation in a curriculum design team (start storyline)?

• reminder: scientific knowledge based on subjects from society, context delivery, concept transfer, concept training, activating teaching strategies, different teacher role, working with other science subjects?
• Expert, intermediate, beginner?
• Why?
• Can you indicate how your knowledge and skills in context-based education have changed during your participation in the design team?
• Inquire after curves, drawn etc.
• You indicate that you are now a (Expert / Intermediate / Beginner). Why?
• The trend you drew in the graph is for 25, 50, 75, 100 percent the result of your participation in the curriculum design team?
• The trend you drew in the graph is for 25, 50, 75, 100 percent the result of activities and experiences outside the design team. They are: . . .

14. Did you use elements of context-based education in your classes prior to your design team participation? (start storyline)?
• reminder: scientific knowledge based on subjects from society, context delivery, concept transfer, concept training, activating teaching strategies, different teacher role, working with other science subjects?

• Never, sometimes, regularly, often?

• Do you have a special reason for doing so?

• Could you indicate whether you use more elements of context-based education in your classes since your curriculum design team participation? (Examples: teaching activities, context-minded, coaching teacher role, cooperation with others?)

• Inquire after curves, drawn etc.

• You indicated that you now (never / sometimes / regularly / often) use elements of context-based education in your classes. Why?

• The trend you drew in the graph is for 25, 50, 75, 100 percent the result of your participation in the curriculum design team?

• The trend you drew in the graph is for 25, 50, 75, 100 percent the result of activities and experiences outside the design team. They are: . . .

15. Can you indicate in this graph what the ratio is in control on student learning between teacher and students in your classroom?

16. To which extent do you cooperate in your school with your own and other science departments?

17. I am interested in the learning that takes place in design teams for curriculum materials. Are there any other learning experiences that you have had, which are important to you and which you would like to share with me?

C.6 Product

Are the results of the design team (the material) related to the design team set-up.

1. Do you still work on the curriculum module? (editing, updating etc.)? Why so /not?
2. Was the curriculum module you made evaluated by an expert when it was finished? Who by, what was their opinion?

3. Would you personally call the curriculum module you helped to design a success? Why so / not?

4. Was the module certified (-ASMaT; other)?

5. Is the curriculum module you made centrally stored and distributed?

6. Who has the copyright of the curriculum module?

C.7 Final questions

1. If you look back, and know what you know now, would you participate in a curriculum design team again? (why so / not)

2. Are there any prerequisites on your part that have to be met before you would consider participating?

3. Would you like me to send you a transcript of this interview, so you could add or change the content?

4. Could I approach you for another questionnaire / interview in the future?

5. Should there be anything you wish to contact me about, feel free to email me.

C.8 Graphical representations used
Figure C.1: question 5.3 Pie chart of subjects of discussions during team work

Figure C.2: questions 5.9 and 5.12 attitude vs time
Interview format teachers with design experience - pilot study

Figure C.3: questions 5.10 and 5.13 experience vs time

Figure C.4: questions 5.11 and 5.14 frequency vs time
Interview format teachers with design experience - pilot study
Appendix D

Emphasis questionnaire

The questionnaire has been taken from Van Driel et al. (2005) and adapted as described in chapter 2 and 3. Below a translated version (Dutch to English) of the questionnaire is provided.

General questions

1. What is the name of the college / school you work at? The name is used for research purposes only and will not be made public in any way.
   School name: 

2. How long have you been teaching high school science?
   - less than one year
   - one to five years
   - five to fifteen years
   - fifteen years or more

3. How old are you?
   - younger than 25
   - 25 - 29 years old
   - 30 - 34 years old
   - 35 - 39 years old
   - 40 - 44 years old
   - 45 - 49 years old
• 50 - 54 years old
• 55 - 59 years old
• 60 years old or older

4. In which science subject do you have the most teaching experience?
   Biology / Chemistry / Physics

5. Do you have any experience in teaching public understanding of science and/or advanced science mathematics and technology?
   Public understanding of science / ASMaT / Both / None

6. Do you have any experience in teaching a science subject in the upper levels of pre-university education?
   yes/no

7. Do you have any experience in teaching a science subject in the upper levels of senior general secondary education?
   yes/no

8. Do you have any experience in teaching a science subject since the 'Tweede Fase'\(^1\) was implemented?
   yes/no

9. On which level did you complete your education?
   • Senior secondary vocational education (MBO)
   • Higher professional education (HBO)
   • University master level (drs. / ir. / MSc.)
   • Doctorate (PhD)

10. In which subject did you graduate or take your PhD in? (biology, chemistry, physics, engineering, etc.)?

11. Which teaching qualification do you hold for the science subject you teach?
    • 1st level / master
    • 2nd level
    • MO-A

---

\(^1\)Educational reform aimed at more student regulated learning in the upper levels of secondary education
12. Do you hold a teaching qualification for public understanding of science?
   yes/no

13. Which teaching method (text book) do you currently use in the upper levels of high school?

14. Have you been (officially) involved in the development of instructional materials?
   If so: please indicate below which book, module, publisher, and the period during which you were involved.

15. Do you use the method you developed in your own classes?
   yes/no

16. Please indicate for which science subject you are filling out this questionnaire
   Biology / Chemistry / Physics

In this section you will find 46 statements about science education

Please indicate your agreement with the given statement.

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1 A science education serves to prepare students for a scientific or technological education, such as medicine, chemistry, and aerospace engineering.

2 I think experiments are important to teach students the process of scientific research.

3 I think it an important task of science education to teach students how scientific knowledge is used to develop new products such as plastics and medication.
4 I think it an important task of science education to teach students that the problem solving strategies used by biologists, chemists and physicists are similar.

5 I think it is an important part of a science education that students learn to argue social topics wherein scientific subject knowledge plays a role.

6 I think it an important task of science education to teach students how products are made on an industrial scale.

7 I think it important that students focus on accurate outcomes during experiments like titrations and the measurement of velocity.

8 I think it an important task of science education for students to acquire insight into the socio-historic development of scientific knowledge.

9 I think it important that in my classes current social topics that involve my science subject are discussed.

10 For me, acquiring scientific skills is important because students need them to carry out analyses for biology, chemistry or physics.

11 When students are working on assignments for my subject, I find it more important that they construct the correct set-up than that they have the correct result.

12 I think it an important task of science education for students to realise that scientific knowledge plays a part in numerous professions, ranging from hairdressers to veterinarians.

13 I think that the school and national exams should be of a level that enables selection for scientific or engineering subsequent education.

14 I think it an important task of science education for students to learn that scientists develop and use models as a tool to solve theoretical and practical issues.

15 It is important to me that students are able to work on assignments that refer to relevant topics and issues in society.

16 It is important to me that my lessons closely follow the historical development of scientific knowledge.

17 I think it an important task of science education for students to learn to use knowledge in my subject field when making personal choices on for instance, food and health care or use of energy.
18 I prefer to orient my classes towards students who consider a further education in science or engineering.
19 I think it an important task of science education for students to realise that scientific knowledge is not completely defined, but open to change.
20 I think it important that my classes deal with societal pro’s and cons for the development of new products (such as medication and MP3 players).
21 I think it is important for students to learn how to model scientific phenomena in my classes.
22 I think it an important task of science education for students to learn how economics (fast and large scale production) are combined with concerns for the environment and safety.
23 I think that students should acquire basic scientific skills before they can work on applications.
24 An important goal of science education for me is that students learn how scientist develop knowledge.
25 I think it important that in my classes the relation between scientific knowledge and relevant societal issues is dealt with.
26 I think it an important task of science education for students to learn to use scientific knowledge to come to personal opinions on societal issues such as the use fossil fuels.
27 I think it an important task of science education for students to realise that human qualities, such as creativity and ambition also play a role in the development of scientific knowledge.
28 I think it is important that students look for background information of my science subject that is relevant for personal matters, such as health.
29 I think it an important task of science education in my field that students learn to see the set-up and internal cohesion of the knowledge of my science subject.
30 I feel it is important that students learn during classes how scientific phenomena are accounted for.
31 I think that the exit qualifications for my subject field should be based on an analysis of societal situations where my subject plays an important part.
32 In my classes the learning of scientific concepts is foremost important.
33 I think it is an important task of education in my subject field that students learn how modern research leads to knowledge in my subject field.

34 I prefer to use societal contexts in my lessons to show what the importance of my science subject is.

35 I think that the exit qualifications of science education should be based on the demands of scientific subsequent education.

36 I think it an important task of education in my subject field that students acquire subject knowledge and skills that they can use in their daily lives -now and in the future.

37 I think that students should first learn how to perform an experiment from paper before they can work on open ended assignments.

38 I want to make clear in my classes which role scientific products have in students’ daily lives.

The following statements concern biology only.

39 I think that biology students should start with learning about cellular construction and functions as a basis for developing biological knowledge.

40 Learning to complete biological calculations is important to me because students can use them to solve biological assignments.

41 I think it is important in my lessons to teach students how the theory of evolution has been constructed.

42 For me, knowledge on proteins is important for students because it is such a fundamental concept in biology.

43 For me, knowledge about the survival mechanisms of organisms is important because it allows students to understand numerous biological phenomena.

44 For me, knowledge about blood circulation is mainly important because it allows students to understand the processes in the human body.

45 I think it is important in my classes to treat the historical background of the evolution theory.

46 I think it is important in my classes to use cells and structures to show the internal coherence of biological concepts.

The following statements concern chemistry only.
39 I think that chemistry students should start with learning a simple atomic model as a basis for developing chemical knowledge.

40 Learning to complete chemical calculations is important to me because students can use them to solve (quantitative) chemical assignments.

41 I think it is important in my lessons to teach students how the periodic table has been constructed.

42 For me, knowledge on acids and bases is important for students because they are such a fundamental concept in chemistry.

43 For me, knowledge of chemical equilibrium is important because it allows students to understand numerous chemical phenomena.

44 For me, knowledge of molecules is mainly important because it allows students to understand the chemical reactions.

45 I think it is important in my classes to treat the historical background of atomic models.

46 I think it is important in my classes to use atoms and molecules to show the internal coherence of chemical concepts.

The following statements concern physics only.

39 I think that physics students should start with learning abstract equations as a basis for developing physical knowledge.

40 Learning to complete physical calculations is important to me because students can use them to solve (quantitative) physical assignments.

41 I think it is important in my lessons to teach students how quantum mechanics has been constructed.

42 For me, knowledge on forces is important for students because they are such a fundamental concept in chemistry.

43 For me, knowledge of energy conservation is important because it allows students to understand numerous physical phenomena.

44 For me, knowledge of charges is mainly important because it allows students to understand electricity.

45 I think it is important in my classes to treat the historical background of radioactivity.

46 I think it is important in my classes to use variables and units to show the internal coherence of physical concepts.
Comments regarding the questionnaire:
## Appendix E

### Rotated factor loadings emphasis questionnaire

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Appendix F

Interview format teachers with curriculum material design experience

F.1 General and motivational questions

1. How old are you?

2. On which level did you complete your education?

3. In which subject did you graduate or take your PhD in? (biology, chemistry, physics, engineering, etc.)?

4. Which teaching qualification do you hold for the science subject you teach?

5. How long have you been teaching and which subject do you read?

6. Do you still teach?

7. What kind of classes are they: context-based, regular etc.?

8. Do you have any other jobs/tasks besides teaching (even outside school)?

9. What is the curriculum module you worked on called? (where could I get hold of a copy?)

10. Why did you join the design team for (name of module)?

11. Were there any other reasons to join the design team?
Interview format teachers with curriculum design experience

- Subject matter
- Student learning
- Coincided with another activity (education, course etc.)
- A personal goal: ...

12. From which moment in time (dates) up to which moment (dates) did you work for the curriculum design team? Are you still involved?

13. Can you describe the background of the people who worked in the curriculum design team with you? (occupation, expertise, role in the team)

F.2 Context and regulation

1. According to you, what does the innovation for your science subject entail?

2. Does the innovation have consequences for the pedagogical approach for your subject? Context-based education versus traditional teaching?
   - Role and implications of the contexts
   - Role and implications of the concepts
   - Role of the student
   - Teacher role
   - Other differences between traditional education and context-based education

3. How did you acquire this knowledge on context-based education?

4. Can you indicate whether any of the following sources has attributed to your knowledge?
   - The design team work
   - A specific member of the design team (who?)
   - A specific course or training (which, who by?)
   - General assemblies for teachers (which?)
   - Information from the innovation committees (what kind?)
   - Other sources: ...?
5. Could you indicate whether you use more elements of context-based education in your classes since your curriculum design team participation? (Examples: teaching activities, context-minded, coaching teacher role, cooperation with others?)

6. Can you indicate in this graph what the ratio is in control on student learning between teacher and students in your classroom?

F.3 Design and the context-based innovation

1. Have you been involved in the design/writing of a curriculum module/textbook before you started on the context-based curriculum module? (Kind of experience, context-based or other, etc.)

2. Did you follow a training or course in designing curriculum materials?

3. What did the course entail? Would you have thought a training/course was necessary?

4. What is the most important element when you start designing curriculum materials?

5. Could you arrange the elements below in order of importance?
   - Having certain team members such as teachers, people with experience in writing materials, coach other?
   - Typographical lay-out
   - Using a structure to work by: a learning continuity pathway, project planning, other?
   - Opportunity to consult experts on the subject chosen.
   - Opportunity to consult pedagogic experts
   - Trying the material made in class
   - Observing colleagues teach: either during the trial run or other occasions
   - Any other important element you think is important: . . . ?

6. Do you design more for your own teaching practice than before you worked in the curriculum design team?
7. What kind of things do you design? Work schedules, additions to textbooks, experiments . . . ? (can I have an example of something you designed?)

8. Do you cooperate more within your science department than prior to your design team experience? Or with other science departments, people outside school?

9. How come?
   - innovation
   - design team work
   - broader interest, different (additional) job
   - more fun to do
   - people are more motivated to work together
   - other . . . ?

F.4 Emphasis

1. Next, I will present three teaching strategies. Could you tell me which one you would prefer and why?
   Teacher A, B and C mean for their students to learn chemical equations.
   Teacher A requires the students to find out how much sulfite should be added to white wine to increase the use-by date, taking care not to exceed the legal health limits.
   Teacher B provides a theoretical explanation on the blackboard and requires the students to complete exercises from their study book, practising the chemical equations.
   Teacher C has the students do experiments, where the students learn the equations by doing, observing and creating.

2. Do you think your choice would have been different prior to designing context-based study module(s)? If so how different and why? If not, why?

F.5 Final questions

1. Would you call the curriculum module you made a success? Why so, why not?
2. Was the curriculum module approved by the innovation committees? (certified or other)

3. I am interested in the learning that takes place in design teams for curriculum materials. Are there any learning experiences that you have, which are important to you and which you would like to share with me?

4. Would you like me to send you a transcript of this interview, so you could add or change the content?

5. Could I approach you if I have a question related to our conversation, to clarify things you said or other?

6. Should there be anything you wish to contact me about, feel free to email me.
The intended new context-based curriculum for four science subjects (AS-
MaT\textsuperscript{1}, biology, chemistry, and physics) in senior general secondary educa-
tion and pre-university education has been the subject of numerous research
and teacher professionalisation efforts in the Netherlands for the last seven
years. Following international forerunners, the context-based approach was
chosen to counter falling interest in future education in science among stu-
dents. The governmentally instituted innovation committees were commit-
ted to have input from teachers as well as university experts as to what
the various curricula should contain. In the discussions on context-based
education the focus has mainly been placed on the details on what a context-
based approach should entail for each science subject. The committees were
prepared to test the new curriculum in years 10-12 in secondary education,
including the national exams, for which they needed new context-based cur-
riculum materials.

These context-based curriculum modules were made by teams of teachers
and academic experts, although the actual line-up of the teams varied, from
one teacher working alone and testing the material in the own classroom, to
several teachers and experts working together with the final product being
edited by a professional editor. The teachers working in these design teams
for context-based curriculum material are expected to have learned more
about the context-based approach than their peers without this experience.
The learning of teachers in design teams for context-based materials was
the topic of this thesis.

The aim was to construct an optimal professional development pro-
gramme for science teachers based on the experiences of these designers.

\textsuperscript{1}Advanced Science, Mathematics and Technology, now known internationally as Na-
ture, Life and Technology (NLT).
First a definition of context-based education that would do justice to the national and international literature needed to be constructed. Then a translation from this definition to the teaching practice was made, by defining five teaching competences important for teaching context-based education. These competences were context handling, regulation, emphasis, design, and school innovation.

The general research question in this thesis was: How does the participation of teachers in context-based design teams (ASMaT, biology, chemistry, and physics) contribute to their professional development towards context-based teaching, and which factors concerning the design experience hinder or facilitate this development?

A composite instrument able to measure the five context-based teaching competences was constructed and tested in a pilot study. Quantitative parts of the composite instrument were evaluated further in two national studies. The composite instrument was found to be valid and reliable for measuring the context-based competence of teachers.

The validated instrument was used in a larger study amongst teachers who designed curriculum materials for the context-based innovation and teachers who were not involved in designing. Designers were found to have acquired more context-based competence than non-designers. An influence of the material used in class on context-based competence was also discovered. Using a combination of context-based curriculum modules and a standard textbook in class resulted in more context-based competence.

The designers were interviewed on their design experience. The answers were analysed to find that some kind of structure should be used when designing curriculum materials. This structure could be a learning continuity pathway, a project planning and task division, or rules of thumb to ensure the designed curriculum material contained everything it should. The context-based teaching competence of the designers was also correlated with characteristics of their design experience. Influencing factors were participants in the team, time spent on designing materials, and use of context-based materials in the own class.

A professional development programme was designed and executed with six teachers using these factors and factors identified from literature on
teacher professional development. The programme was successful in chang-
ing teachers context-based competences.

The general conclusions include the confirmation of the five teaching
competences in demand in context-based education as well as suggestions
for additions to these competences. As stated above, not only has design-
ing curriculum materials been found to influence context-based teaching
competency, but also the use of a combination of standard textbook with
context-based curriculum modules has a positive influence. For a profes-
sional development programme success factors have been identified, both
general and specific to context-based education. These findings can be use-
ful to the teaching practice, textbook publishers, institutions for teacher
professional development and teacher training.
Samenvatting

De voorgenomen vernieuwingen van de curricula van vier bètavakken (biologie, natuurkunde, NLT en scheikunde) op basis van de concept-in-context benadering voor de bovenbouw van het HAVO en het VWO is de afgelopen zeven jaar het onderwerp van veel Nederlandse wetenschappelijke onderzoeken en docentprofessionaliseringstrajecten geweest. In navolging van internationale voorbeelden is de concept-in-context benadering gekozen, om de afgenomen interesse onder leerlingen voor bèta-vervolgstudies een halt toe te roepen. De door de overheid ingestelde vernieuwingscommissies legden zich erop toe om zowel docenten in het middelbaar onderwijs als onderwijskundige en vakdidactische experts te betrekken in het opstellen van die nieuwe curricula. In de discussies over de concept-in-context benadering werd vooral gekeken naar wat deze benadering voor elk van de bètavakken in moest houden. De commissies hadden het voornemen om de nieuwe curricula voor 4 en 5 HAVO en 4, 5 en 6 VWO in de praktijk uit te proberen, tot en met het centraal schriftelijk eindexamen. Hiervoor waren concept-in-context lesmaterialen nodig.

De concept-in-context lesmaterialen zijn gemaakt door teams van docenten en experts van hogescholen en universiteiten, alhoewel de werkelijke samenstelling van de teams nogal wisselde: van één docent die het zelfgegemaakte materiaal in de eigen lessen test, tot verschillende docenten en experts samen, waarvan het eindproduct door een professionele editor werd afgewerkt. Van de docenten die in deze ontwikkelteams voor concept-in-context lesmaterialen hebben gewerkt wordt verwacht, dat deze meer over de concept-in-context benadering hebben geleerd dan hun collega’s zonder deze ervaring. Het leren van docenten in ontwikkelteams voor concept-in-context lesmaterialen was het onderwerp van dit proefschrift.

Het doel was een zo optimaal mogelijk professionaliseringstraject voor bètadocenten te ontwerpen gebaseerd op de ervaringen van deze docenten.
met ontwikkelervaring. Daarvoor is eerst een definitie van de concept-in-context benadering opgesteld, die recht doet aan zowel nationale als internationale literatuur. Vervolgens is een vertaling van deze definitie naar de lespraktijk gemaakt, door het definiëren van vijf docentcompetenties die belangrijk zijn voor het lesgiven middels de concept-in-context benadering. Deze competenties waren: omgaan met de context, docentregulering, docentemfase, ontwikkelen en innoveren binnen de school.

De algemene onderzoeksvraag in dit proefschrift luidde: *Op welke wijze draagt de deelname van docenten aan ontwikkelteams voor concept-in-context lesmaterialen (biologie, natuurkunde, NLT en scheikunde) bij aan hun professionele ontwikkeling tot het lesgiven met deze benadering en welke factoren in de ervaring met ontwikkelen van lesmateriaal storen of vergemakkelijken deze ontwikkeling?*


De docent-ontwikkelaars zijn geïnterviewd over hun ontwikkelervaring. Een analyse van de antwoorden leverde op dat een soort structuur belangrijk is wanneer men lesmateriaal ontwikkelt. Zo'n structuur zou een leerlijn kunnen zijn, maar ook een projectplanning en taakverdeling, of vuistregels waardoor zeker wordt gesteld dat het ontwikkelde materiaal alles bevat wat nodig is. De concept-in-context competentie van de docent-ontwikkelaars is gecorreleerd met achtergrondvariabelen rond het ontwikkelen van lesmateriaal. Factoren die van invloed bleken te zijn waren: de deelnemers aan het ontwikkelteam, de duur van de ontwikkelervaring en het gebruik van de concept-in-context modules in de eigen klas.
Gebruik makend van de hierboven gevonden factoren en factoren bekend uit literatuur is een professionaliseringstraject ontworpen en uitgevoerd met zes docenten. Het traject bleek succesvol te zijn in het veranderen van de concept-in-context docentcompetenties.

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En Sander, voor alles
Lesley de Putter-Smits was born on the 19th of February, 1977 in Leiderdorp, The Netherlands. She obtained her MSc-degree in chemistry at Utrecht University in January 2000. Her MSc-thesis, entitled "A platination studies of N,C,N’ and P,C,P’-type ligands" dealt with the synthesis of a platinated hexa pincer cartwheel, a molecule designed to be used as a reusable catalyst in industrial synthesis processes. After a period of travelling and working for an insurance company, she was accepted into the post-graduate programme Process and Product Design at the Stan Ackermans Institute in Eindhoven in September 2001. The final project of the Stan Ackermans programme was performed at SABIC in Geleen and focussed on the design of systems for operator safety at a naphta cracker. After concluding this work, she started as a physics teacher at the Heerbeeck College in Best in September 2003, pursuing a teacher training programme at the Eindhoven University of Technology at the same time. In September 2007 she started her PhD-studies at the Eindhoven School of Education, Eindhoven University of Technology funded by the DUDOC-programme combined with her teaching job in Best.

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