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Empowering chemistry teachers for context-based education

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Empowering chemistry teachers for context-based education

Towards a framework for design and evaluation of a teacher professional development programme in curriculum innovations

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EMPOWERING CHEMISTRY TEACHERS FOR CONTEXT-BASED EDUCATION

Towards a framework for design and evaluation of a teacher professional development programme in curriculum innovations

EMPOWERMENT VAN SCHEIKUNDEDOCENTEN VOOR ONDERWIJS MET CONTEXTEN

Naar een raamwerk voor ontwerp en evaluatie van een professionaliseringsprogramma voor docenten in curriculuminnovaties

(met een samenvatting in het Nederlands)

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Chapter 1

Introduction and overview

Introduction

The research presented in this thesis focuses on the empowerment of teachers for context-based chemistry education. Contexts are becoming more widely used in upper secondary chemistry education, because context-based curricula can solve the problems experienced with traditional, concept-based curricula (Pilot & Bulte, 2006). For successful context-based innovation, researchers and policymakers advocate that teachers should participate in the design of innovative context-based teaching materials (Driessen & Meinema, 2003; Parchmann, Gräsel, Baer, Demuth & Ralle, 2006). Next to substantial changes in their practice, teachers shift from using teaching materials developed by others to designing and teaching their own materials. For such innovation to be successful, it is important that teachers feel empowered for change.

To prepare teachers for change, educational innovations are usually accompanied by professional development programmes. Research focuses mostly on evaluating the outcomes of these programmes in terms of changes in teacher cognitions and practices or improvement of students' results. Little attention is given to the processes of professional development during these programmes. Insight into these professional development processes can provide valuable information for the programme's design (Hewson, 2007). The research described in this thesis aims to acquire more understanding of the contribution of the activities in the process of teachers' professional development that lead to their empowerment. At a more general level, it aims to contribute to the knowledge base on how to design and evaluate professional development programmes for context-based curriculum innovations.

In this chapter we present an introduction to the research described in this thesis. A detailed description of the theoretical issues, method, results and conclusions is given in Chapters 2 to 6.

Context-based chemistry education

Current chemistry curricula in upper secondary education are mainly concept-based. In such curricula, chemistry is usually presented as a cumulative and static body of theoretical knowledge to be memorised and skills to be practised. This traditional approach has become the subject of criticism among stakeholders (teachers, teacher educators, policymakers, and researchers). First, school chemistry is considered to be isolated from society and students (Van Berkel, De Vos, Pilot & Verdonk, 2000). It focuses mostly on concepts and pays little attention to the societal, technological and personal aspects of chemistry. Second, research on students' conceptions of chemistry topics has convincingly demonstrated that students often end up with a poor understanding of chemistry concepts (De Jong & Taber, 2007). Concept-based chemistry curricula are also known to be overloaded and to hinder transfer of knowledge (Gilbert, 2006). Finally, as a result of to the lack of attention to student input (Westbroek, 2005), concept-based chemistry education is insufficiently aligned with contemporary pedagogical innovations which emphasise students' self-regulated and active learning (Bakkenes, Vermunt & Wubbels, 2010).

Increasingly, contexts are being introduced in chemistry curricula across the globe (George & Lubben, 2002; Pilot & Bulte, 2006; Smith, 2011). Contexts address these problems as follows. First, context-based chemistry education is intended to be relevant to all students. By focusing on the societal, technological and personal aspects of chemistry, chemistry education should become more meaningful for all students. Second, contexts are used as a starting-point for learning new concepts. Contexts are intended to provide a rationale for both selecting and studying chemistry concepts. On the basis of the 'need to know' principle (Bulte, Westbroek, De Jong & Pilot, 2006), it is decided what concepts should be addressed in the teaching unit, so only those concepts that are needed with respect to the context are selected. Contexts should induce the 'need to know' among students, providing a motive to know more about new chemistry concepts and thereby giving meaning to these concepts. Learning chemistry concepts based on the 'need to know' principle should also enable transfer and gradual abstraction of chemistry knowledge (Vos, Taconis, Jochems & Pilot, 2011). Finally, context-based chemistry education aims to actively involve students in their learning of chemistry. Through contexts, students give shape to their own learning of chemistry, finding solutions to real, context-based problems, by asking and refining questions, and by designing and conducting investigations. These activities require students to collaborate with peers, relate new chemistry content to their daily life inside and outside school, and stimulate self-regulated behaviour and thinking (Parchmann et al., 2006).

Context-based innovations have implications for teaching chemistry (King, Bellochi & Ritchie, 2008). First, teachers will be confronted with the challenge of teaching chemistry in a way which appeals to all students and not just students with high abilities or high motivation for chemistry. Second, instead of transmitting content knowledge, the emphasis in teaching will be on using contexts, enabling students to learn chemistry content meaningfully. Moreover, teachers will be asked to pay more attention to the relation between chemistry and societal or personal issues, aspects of chemistry they usually ignore or do not feel very comfortable with. Finally, this method of learning will require teachers to step back in controlling students' learning activities, and to coach students in shaping their learning of chemistry. The implementation of contexts will cause profound changes in the learning and teaching of chemistry. For a successful shift from a concept-based to a context-based curriculum, chemistry teachers' involvement in the innovation is essential (Bennett, Gräsel, Parchmann & Waddington, 2005).

Teachers and educational innovation

Teachers are considered the most important agents in shaping a new curriculum and bringing about change in educational practices (Fullan, 2007). In most curriculum reforms, however, a small group of experts are to design the new teaching materials. Teachers are then supposed to teach these prescribed materials, without the opportunity to bring in their own ideas and experiences and with little opportunity for training. Often, such curriculum innovations have failed because they did not recognise the need for teacher professional development (Van Driel, Beijaard & Verloop, 2001). Bringing sustainable change in educational practices requires a complex and far-reaching process. Teachers need to develop a new vision, to adjust to the new content and pedagogy, to understand what the innovation is good for, to develop appropriate skills and to reflect on their experiences in order to learn (Vos et al., 2011).

To accomplish such learning process, teachers should not only implement innovations, but they should also become actively involved in the design of innovations (Altrichter, 2005). Teachers in the role of designer will result in new, innovative teaching materials which can be recognised as such by other teachers and which are closely linked to their practical knowledge and beliefs. This reduces the feeling among teachers of being forced to change their practices, and can avoid incongruence between what is intended and what occurs in classroom practice. In addition, acting as designers will help teachers to develop their thinking about the new curriculum. Through design activities, teachers can gain commitment and ownership with respect to the educational change (Vos et al., 2011).

However, teachers generally are not experienced designers. Whereas they regularly adapt existing teaching materials for their lessons, many do not feel confident in designing new, innovative teaching materials and they often have difficulties with thinking as designers do (George & Lubben, 2002; Penuel & Gallagher, 2009). To successfully involve teachers in designing and implementing new context-based teaching materials professional development is required. This professional development should focus on empowerment of teachers as designers of new innovative teaching materials.

The need for a professional development framework

The research described in this thesis focuses on professional development leading to empowerment of chemistry teachers for context-based chemistry education. Such a focus means specific outcomes can be connected to specific elements of the programme for better understanding of which elements contribute to certain outcomes. Also, the interaction between teachers' knowledge and beliefs and the programme, together with the consequences of these interactions for both the programme and the teachers, can become more visible To investigate the professional development that leads to teacher empowerment, a programme needs to be designed, conducted and evaluated. This requires a description of such professional development and the requisite design principles .

Several general frameworks have been published, each highlighting different aspects of science teachers' professional development. That of Bell and Gilbert (1996) focuses on teachers participating in professional programmes and describes interrelated strands of their personal, social and professional development. Loucks-Horsley, Love, Stiles, Mundry and Hewson (2003) highlight the need for developers of such programmes to pay explicit attention to a range of knowledge bases, to the wide variety of strategies of professional development, to the context of particular programmes, and to critical issues that arise in the design of such programmes. Fishman, Marx, Best and Tal (2003) stress the importance of being explicit about the connections between programme, teacher practice and student learning. But Bell and Gilbert's framework does not provide information on how to design professional development programmes. The frameworks described by Loucks-Horsley et al. (2003) and Fishman et al. (2003) solely focus on professional developers and both lack an adequate description of teacher development. Although these frameworks provide valuable insights on teachers' development and designing professional development programmes, they do not provide a framework for the design of professional development programmes and for the analysis of teacher learning during these programmes. Therefore, a new framework has to be developed which integrates aspects of existing frameworks and teacher learning during context-based curriculum innovations. This framework should provide principles on how to design and evaluate such programmes and provide predictions of the professional development that is expected to take place.

Research question and research strategy

The aim of the research described in this thesis is to acquire more understanding of the contribution of the activities in the programme to teachers' professional development which leads to their empowerment in context-based chemistry education. On a more general level, it aims to contribute to the knowledge base on how to design and evaluate professional development programmes for context-based curriculum innovations. The knowledge involved in this research will be captured in a framework. The general research question addressed in this thesis is:

> *What constitutes a professional development framework for designing and evaluating a programme to empower chemistry teachers for context-based education?*

To answer the research question, a design-based research approach was applied (Lijnse, 1995; Cobb, Confrey, diSessa, Lehrer & Schauble, 2003; Bulte et al., 2006: McKenney, Nieveen & Van den Akker, 2006). Based on a review of the literature, a theoretical framework for initiating teacher empowerment was designed. Subsequently, it was elaborated and adapted in two empirical research cycles that focused on implementation and evaluation of both the framework and the programme. The framework was also used to describe the design in detail and to evaluate the professional development leading to teachers' empowerment that was expected to take place. Discrepancies between the designed programme and the realised programme were analysed and used to improve the programme and framework. Testing of the designed programme took place in small-scale case studies, with groups of teachers as the unit of analysis.

Background of the study

The innovation of chemistry education in Dutch upper secondary education started in 1998, when a group was formed consisting of researchers in chemistry education, chemistry teachers, teacher educators and curriculum experts. This group, which was called the Eenhoorn Group (Unicorn Group), identified the isolated position of school chemistry with respect to society and students' daily life (Bulte et al., 1999). To make school chemistry education more meaningful to students, the Eenhoorn Group suggested embedding chemistry concepts in contexts. A context-based chemistry curriculum should consist of a series of units. Each unit should be designed from a context, and structured according to a general context-based model (see Chapter 4) which consists of three parts: a context-based introduction, chemistry concepts, and context-based projects. The Eenhoorn Group labelled their context-based proposal 'Nieuwe Scheikunde' (New Chemistry) (Bulte et al., 2000). The Eenhoorn Group also developed an exemplary context-based unit for 16-year-old pre-university students about super-absorbent material in disposable diapers (Jansen & Kerkstra, 2001).

The Eenhoorn Group also advocated that teachers should be actively involved in all stages of the innovation process. To design and implement new context-based units, they proposed a model consisting of a network of teacher design groups. Initially, a group of curriculum experts, researchers and teachers were to design and field-test an exemplary context-based unit. Subsequently, this unit is distributed to the teacher design groups, which design new context-based units. Gradually, both the number of groups in the network and the number of new context-based units should be increased.

In 2002, a governmental committee explored whether stakeholders would support a revision of upper secondary school chemistry education. The committee held a series of interviews with students, teachers, teacher educators, chemistry education researchers, chemistry professors and representatives of the chemical industry and the professional organisation of chemists. The committee confirmed the analysis of the Eenhoorn Group. They observed that there was a gap between the image of chemistry presented at school and modern chemistry in science and industry. Also, they argued that there was little attention paid to practical assignments and research in chemistry classes. They concluded that 'there is a large consensus that the upper secondary school chemistry curriculum should be reformed' (Van Koten, De Kruijff, Driessen, Kerkstra & Meinema, 2002, p. 21).

A follow-up committee investigated the nature and content of a new chemistry curriculum, and proposed an organisational model for its design and implementation. In August 2003, the committee followed the Eenhoorn Group's stance and advocated a context-based approach to address the identified problems. For the design and implementation of the new curriculum the committee proposed an organisational model in which 'Networks of teachers, supervised by a coach, develop, test and evaluate new units' (Driessen & Meinema, 2003, p. 39). A Project Group, which was responsible for the actual curriculum design, supervised these networks. A National Steering Committee, consisting of curriculum stakeholders and policymakers, supervised the Project Group. The National Steering Committee was responsible for the framework of the chemistry curriculum and the process leading to a context-based chemistry curriculum. Each teacher group had to consist of at least three chemistry teachers from different schools and a coach. The Project Group framed the characteristics of the context-based units and the Ministry of Education together with school administrations facilitated the first groups of teacher-developers by reducing their workload and agreed to let teachers use the developed material in their classes.

In 2004, eight groups were initiated, in which teachers from 41 different schools started to design 15 different context-based units. In the period 2005-10, these groups designed 45 different context-based units, which were distributed among 170 schools. In the meantime, the National Steering Committee created a new national examination programme which is planned to be implemented in 2013. In 2008 the innovation entered a new stage, and new design groups were set up with new teachers and coaches (Apotheker et al., 2010).

The study presented in this thesis was mainly carried out during the early stages of the innovation, from 2000 until 2004. During this stage, the context-based curriculum innovation evolved from a call for discussion by a small group of concerned curriculum stakeholders to a nation-wide project supported by the Dutch Ministry of Education.

Overview of the thesis

In this section, we present a brief overview of the chapters. Chapters 2, 3 and 4 can be considered part of the first research cycle. Chapters 2 and 3 are theoretical articles, in which the synthesis of the professional development framework is described. Chapter 4 is an empirical article in which a programme based on the framework is designed, carried out and evaluated. Chapter 5 can be considered part of the second research cycle. In this chapter a refined version of the framework is presented and a new programme based on this framework is designed, implemented and evaluated. Chapter 6 summarises the findings, presents conclusions and provides a reflection on the evolving insight on how to synthesise a professional development framework for designing and evaluating a programme to empower teachers for context-based chemistry education. Since the chapters build on each other and incorporate insights from previous research, each chapter has specific research questions and its own focus. Figure 1 provides an overview of the chapters of this thesis.

Chapter 2: Towards a professional development framework: Goals, strategies and rationale

This chapter describes the first step in the synthesis of a professional development framework by identification of suitable goals and appropriate professional development strategies. Analysis of the literature on context-based and teacher-based curriculum innovations resulted in three suitable goals and four appropriate professional development strategies. Subsequently, the operationalisation of these strategies in different empirical studies on professional development programmes was analysed. A specific sequence of events for designing teaching materials was identified. Also, it appeared that these studies lack a clear relation between goals, strategies and activities. They focus mostly on the outcomes of the professional development programmes. There is also little attention paid to the contribution of programme activities to teachers' professional development process. It was concluded that a framework should contain a learning theory which describes the process of professional development.

Chapter 3: Towards a professional development framework: Learning theory and synthesis

This chapter describes the second step in the synthesis of the professional development framework by identification of an appropriate learning theory and the design of the framework. Several contemporary learning theories are presented. A suitable learning theory was selected that was

	Chapter 1 **Introduction and overview** General research question: What constitutes a professional development framework for designing and evaluating a programme to empower teachers for context-based chemistry education?
	Chapter 2 **Towards a professional development framework: Goals, strategies and rationale** In this chapter the goals and strategies are presented for a professional development framework for designing and evaluating a programme to empower chemistry teachers for context-based education.
First Research Cycle	**Chapter 3** **Towards a professional development framework: Learning theory and synthesis** This chapter describes the synthesis of a learning theory, goals and strategies in a framework for professional development to empower chemistry teachers for context-based education.
	Chapter 4 **Evaluation of a professional development framework to empower chemistry teachers for context-based education** This chapter describes an elaboration of the framework into a programme for professional development. The enactment and evaluation of the programme with a group of experienced chemistry teachers are presented.
Second Research Cycle	**Chapter 5** **Evaluating a refined professional development framework to empower chemistry teachers for context-based education** This chapter considers the refined framework and its elaboration into a new programme. The enactment and evaluation of the new programme with a new group of experienced chemistry teachers are described.
	Chapter 6 **Conclusions and reflection** This chapter summarises all major findings and conclusions of the study. It reflects on the both the findings and the research method.

Figure 1: Overview of the thesis.

based on the goals and strategies from Chapter 2. This learning theory was then synthesised with the strategies and goals into a framework. This framework should also act as a practical tool for designing a programme and for investigating the professional development processes that take place during the enactment of the programme. It was concluded that empirical research with the framework was feasible and necessary.

Chapter 4: Evaluation of a professional development framework

This chapter explores the implementation and evaluation of a programme based on the professional development framework. First, the framework was elaborated into a programme to empower chemistry teachers for context-based chemistry education. The programme consisted of teaching a context-based unit, followed by designing an outline of a new context-based unit. Subsequently, the programme was implemented and evaluated. Six experienced chemistry teachers participated in the programme. The findings indicate that the intended professional development process only happened in part and that teachers became only partially empowered to design context-based chemistry education. From the detailed findings on the process, revisions of the framework and the programme were proposed.

Chapter 5: Evaluating a refined professional development framework

This chapter describes the refined professional development framework, its elaboration into a new programme, and the implementation and evaluation of the programme. The programme was carried out with a new group of seven chemistry teachers. Evaluation of the programme focused on revisions of the programme, and to what extent the teachers did indeed feel empowered for context-based chemistry education. The findings indicated that teachers become empowered to design context-based chemistry education, provided that they have sufficient time and resources. The findings also showed the sizable influence of the curriculum leader and the teachers' professional knowledge on the professional development process. The results were used to reflect on the professional development framework. Implications for the programme and the framework were discussed.

Chapter 6: Conclusions and reflection

This chapter summarises all major findings and conclusions of the four studies. A discussion of the findings and the relevance of the professional development framework related to the literature are presented. Finally, the general research question is answered, and implications are formulated for researchers, teacher educators and policymakers.

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Chapter 2

Towards a professional development framework: Goals, strategies and rationale

This chapter describes the first step in the synthesis of a professional development framework, identification of suitable goals and appropriate professional development strategies. Analysis of literature on several context-based and teacher-based curriculum innovations results in three suitable goals and four appropriate professional development strategies. Subsequently, the operationalisation of these strategies in different empirical studies on professional development programmes is analysed. It appeared that these studies lack a clear relation between goals, strategies and activities, that these studies focus mostly on the outcomes of the professional development programmes and that there is little attention for the contribution from programme's activities to teachers' professional development process. It is concluded that a framework should contain a learning theory which describes the process of professional development.

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Strategies for a professional development programme: Empowering teachers for context-based chemistry education

Abstract

The aim of this study is to understand the design of professional development programmes in teacher-based and context-based chemistry curriculum innovations. Firstly, the goals of these programmes are discussed and related to the concept of empowerment. Next, in a selection of empirical studies, four general strategies for professional development are analysed (providing access to innovative units, organising reflection, collaboration and organising the design of innovative units by teachers). This analysis results in two outcomes: (1) a sequence of events for teacher-based and context-based curriculum design and (2) the conclusion that in these studies explicit relations between the goals, the strategies and the activities in these programmes are lacking; they should be made more explicit. It is recommended that a theory for teacher professional development should be used to describe these relations.

Aim and outline

A substantial change in the teachers' role and repertoire is needed when teachers become involved in designing new curricula (cf. Anderson & Mitchener, 1994). Traditionally, a small group of curriculum experts defines new curricular aims and designs corresponding curriculum units. The teachers' role is limited to executing these new units. Over the years, researchers have advocated that teachers should become involved in the design of new curricula (Schwab, 1983; Marsh, 2004). Through designing new curricula, teachers can gain commitment and ownership with respect to the innovation, thus enabling a substantial change in their knowledge, skills, beliefs, in their attitudes about their teaching and helping them become acquainted with new subject matter.

A curriculum innovation in which teachers participate in the design of new curriculum units (a teacher-based curriculum innovation) requires appropriate professional development. Teachers generally do not have the experience to design innovative ready-to-use curriculum units (Bencze & Hodson, 1999), and they generally do not regard themselves as designers of new and innovative units (Eisenhart, Cuthbert, Shrum & Herding, 1988). Additionally, Van den Akker (1994) stated that teachers' knowledge, skills, beliefs, attitudes about an innovation may be rather superficial before they experience the consequences of this innovation in practice. Moreover, Loucks-Horsley, Love, Stiles, Mundry & Hewson (2003) argued that teachers need sufficient time and resources to design innovative units. Thus, besides a change in teachers' knowledge, skills, beliefs, and attitudes, a teacher-based curriculum innovation involves a change in the way teachers view their role during the curriculum innovation: they become active designers of a new curriculum. It is therefore necessary to professionally develop teachers in such a way that they become empowered to design a new curriculum. Recently several context-based teacher-based curriculum innovations were initiated (see the third section). To empower teachers for designing context-based chemistry education requires a professional development programme. The aim of this study is to understand the effectiveness of programmes for professional development and to contribute to the design of professional development programmes for chemistry curriculum innovations by identifying the principles for the design of such programmes. In this paper we focus on three research questions. They are designed to address the goals of these programmes, the strategies and activities to attain them and the relations between the goals and the means of attaining them.

1. What are the goals of professional development programmes directed at context-based and teacher-based curriculum innovations?
2. What type of strategies and activities can be identified in these professional development programmes?
3. What are the relations between the goals of these programmes and the strategies and activities in these programmes?

Method

To answer the first research question, literature on context-based and teacher-based curriculum innovation was analysed according to the framework of Goodlad (Van den Akker, 1998). To answer the second research question, contemporary handbooks and review papers on teacher professional development and teacher learning were examined for strategies and activities used in professional development programmes. Four strategies were selected which are generally accepted and most in accordance with teacher professional development in a teacher-based curriculum reform. To assess how the strategies and activities are specified and framed into professional development programmes (the third research question), empirical studies were selected (with the four strategies as the criterion for selection) and examined. These studies focus on the design and evaluation of specific professional development programmes for experienced science teachers.

This paper gives an analysis of an informed selection of the literature on science curriculum reform and evidence of the results of (the accompanying) professional development programmes. Although this paper uses context-based chemistry education as an example, answers to research questions 2 and 3 are not limited to context-based chemistry or science curriculum innovations. The answers apply to different kinds of science curriculum innovations, such as inquiry-based and transformational innovations (Keys & Bryan, 2001; Pilot & Bulte, 2006) as well.

In this paper the terms '*design*' and '*development*' are used in the following way. Design is used to describe the activities of generating a (unit of a) programme for students or teachers, from an idea down to the details that are needed for teaching and learning (including the details of the curriculum units). The designed programme is one of the results of these design activities. Development is used in 'professional development programme' of teachers. This study focuses on the professional development of teachers as it is induced by the designed framework, not on the designed activities of a unit or a programme.

Professional development in teacher-based and context-based curriculum innovation

Curriculum and curriculum innovation

When empowering teachers for teacher-based curriculum innovation, the term 'curriculum' needs clarification. This term is used in many situations and has a broad meaning with many appearances (Marsh, 2004). The curriculum representations of Goodlad (Van den Akker, 1998) can be helpful to distinguish between the different appearances. The *ideal* curriculum represents the original vision, philosophy, rationale or mission underlying the curriculum. In the *formal* representation of the curriculum this vision is elaborated in a curriculum document. The *perceived* curriculum gives the description of the curriculum, as its users, especially teachers, perceive it. The *operational* curriculum represents the actual instructional process in the classroom. The *experiential* curriculum describes the actual learning experiences of the students, and the *attained* curriculum represents the resulting cognitive and affective learning outcomes with the students. Next to this typology, a curriculum can be considered at a macro level, which is generally a national or state level, and at a micro level, which is generally the classroom level. At a national or state level policy decisions are made about the ideal curriculum. These policy decisions inform the operational curriculum inside a classroom: the actions of a teacher anticipating the actions, knowledge and motives of the students. An attained curriculum can be considered at a micro level: the outcomes of a test or a series of tests of one class. When discussing the outcomes of a national exam, this relates to the attained curriculum at a macro level.

Science curriculum innovation is usually induced when at a macro level stakeholders experience incongruence between the ideal curriculum and the attained curriculum. For example, policy makers claim that science curricula should involve students in a meaningful learning process, and should show how scientific developments have consequences for students' everyday lives (National Research Council, 1996; Ware, 2001; High Level Group, 2004). However, it is reported that students experience the learning of science in current science curricula, as distant and abstract (Osborne & Collins, 2001; Gilbert, 2006). As a result, teachers experience incongruence between the aims and the outcomes. Innovation can also be induced at a micro level. Teachers carry out the innovation, when they are involved in the development of curriculum units (formal curriculum), when they select such units (perceived curriculum), plan and enact the teaching and learning activities (operational curriculum), and when they assess their students (attained curriculum).

Designing context-based curricula

Over the years, in several countries context-based chemistry curricula have been designed and introduced (Bennett & Holman, 2002). The implementation of context-based chemistry education aims to resolve the problematic features of traditional chemistry curricula. In contrast to conventional chemistry curricula, context-based approaches aim to connect the learning of chemistry to the students' daily life, and make the curricula more meaningful for students by introducing new concepts on a 'need-to-know' basis (Bulte, Westbroek, De Jong & Pilot, 2006). In the past decades several context-based curricula (in both chemistry and physics) have been designed ranging from the inclusion of single units within an existing curriculum to a complete three to four year programme. Examples of such design projects are the Dutch 'PLON' Physics project (Kortland, 2005), the British 'Salters Science and Chemistry' projects (Campbell et al., 1994; Bennett & Lubben, 2006), the American 'Chemistry in Context' (Schwartz, 2006) and the German 'Chemie in Kontext' project (Parchmann, Gräsel, Baer, Demuth & Ralle, 2006). These curricula share the characteristic that the learning of science is introduced on a 'need-to-know' basis depending on the problems or issues that are raised by an introductory context. Contexts should provide for a relevance to learn science; it should also enable students to learn science in a coherent way giving meaning to the concepts to be acquired. See Pilot and Bulte (2006) for a more elaborate overview of the use of contexts in chemistry education.

Innovation of the chemistry curriculum in the Netherlands

The study presented here is related to a national innovation of the chemistry curriculum in the Netherlands. As in many countries, the chemistry curriculum for upper secondary education in the Netherlands, traditionally, has focused on the learning of chemical concepts and skills (De Vos, Bulte & Pilot, 2002). A national discussion about the problematic features of the chemistry curriculum, initiated in 1999, revealed that a substantial leading group of chemistry teachers found their current curricular situation unsatisfactory (Pilot & Van Driel, 2001). In other words, an essential first stage of teacher professional development has already been accomplished: awareness and acceptance among teachers that their practice is problematic. Subsequently, in 2000, a group of concerned curriculum experts proposed to embed the chemistry content more into contexts that students recognise (Bulte et al., 2000). This proposal was in accordance with the beliefs of the Dutch chemistry teachers who preferred a curriculum with more emphasis on the societal aspects of chemistry (Van Driel, Bulte & Verloop, 2005). The group also advocated an innovation approach involving teachers in the curriculum design process by establishing networks of teachers for the design and evaluation of context-based units. Similar to the 'Chemie in Kontext' project in Germany (Parchmann et al., 2006), the group proposed this innovation approach for the design and implementation of this new, context-based curriculum. A few years later the recommendations of the expert group were taken over by a ministerial committee, and became the official policy of the Dutch Ministry of Education (Driessen & Meinema, 2003).

Teacher-based curriculum innovation

Contrary to the situation in a traditional curriculum innovation, in teacher-based curriculum innovation teachers and experts work together to innovate a curriculum. According to Schwab (1983, p. 245), "*teachers should be involved in debate, deliberation and decision about what and how to teach*." This implies decision-making at the micro-level influencing decisions at the macro-level. This reduces the feeling among teachers of being forced to change their practices, and can avoid large incongruence between the ideal, formal and operational curriculum.

Teacher-based curriculum innovation could be organised in the following way. Based upon an initial ideal curriculum, including a general model of the formal curriculum, a group of teachers design innovative units according to this model (see e.g. Eilks, Parchmann, Gräsel & Ralle, 2004). They test these units in their own classrooms and evaluate their experiences. Next, these innovative units are distributed among other groups of teachers who will also test and evaluate them. Moreover, they can use the units as an exemplar for designing new units and so on. In this approach, curriculum design is seen as giving contents to a general model of a new curriculum. The teachers gain control of their active engagement in the process of curriculum design, and they become empowered for teacher-based curriculum innovation (George & Lubben, 2002). In addition to providing teachers with this sense of ownership, the newly designed curriculum units are field-tested by colleagues ensuring the practicability of the units.

Goals for professional development for designing a context-based curriculum
At a macro level there is consensus that a context-based chemistry curriculum helps to address the problematic features of chemistry education in the Netherlands, and that teacher-based curriculum innovation is a suitable approach (Driessen & Meinema, 2003). If this context-based curriculum is to be implemented, it has to be specified in a general model for designing context-based units (formal curriculum at a macro-level). At a micro level, teachers need to understand the context-based nature of the innovation. Furthermore, teachers should develop skills to design context-based units, by participating in the design of context-based units for the new curriculum. This professional development also implies that the teachers should feel confident to take up an active role in the innovation process. These three aspects are the ingredients for empowering teachers for teacher-based curriculum innovation. Based on these ingredients, the following goals for a professional development programme are formulated:

Goal i: The teachers understand the use of contexts in teaching chemistry.
Goal ii: The teachers are able to apply the knowledge about contexts when *designing* new context-based units.
Goal iii: The teachers feel *confident* about their role as designers of context-based units.

For operationalisation of the term 'confident', the following dimensions for teacher empowerment are useful: involvement in decision-making, autonomy, professional growth, and self-efficacy (Short & Rinehart, 1992; Posnanski, 2002; Bogler & Somech, 2004). When expressing the goal 'to feel confident' for an active role in curriculum innovation, teachers have the perception that they are involved in the decision-making process. They recognise that they have control about choices in the curriculum innovation process (autonomy). They perceive that the conditions in which curriculum innovation can take place provides them with the opportunity to grow and to develop professionally (professional growth). It is their perception that they can be effective in building programmes for students and to influence the students' learning (self-efficacy).

Strategies for professional development

There is no one best way to organise professional development in a curriculum innovation (Hawley & Valli, 1999). Rather, for promoting changes in teachers' knowledge, abilities and beliefs, multiple strategies are necessary (Darling-Hammond & McLaughlin, 1995). Regarding the aims of our project we selected the following four strategies that are generally accepted for professional development: *providing access to innovative units* and providing opportunities to practise with these units, *organising reflection* on practical experiences, *stimulating collaboration* with peers, coaches and supervisors, and *organising the design of innovative units by teachers* (Bell & Gilbert, 1996; Marx, Freeman, Krajcik & Blumenfeld, 1998; Van Driel, Beijaard & Verloop, 2001; Loucks-Horsley et al., 2003). It is essential that there is sufficient time to carry out the professional development activities, and that these activities are carried out in a safe and supportive environment (Joyce & Showers, 2002).

Providing access to innovative units

Innovative units for teaching fulfil an important role during curriculum innovation (Ball & Cohen, 1996; Davis & Krajcik, 2005). In a traditional implementation process, these units are used to provide teachers with clarity and the possibility to explore the practical consequences of an innovation during its initial stages of implementation. Together with procedural specifications how to teach, the units provide teachers with an orientation on the new task, and support them in performing aspects of this task with which they would otherwise have difficulties. In other words, innovative units can stimulate teachers to develop their teaching repertoire, by expanding their 'zone of proximal development' (Van den Akker, 1994).

In *teacher-based curriculum innovation*, the units can be used as exemplars to communicate the practical consequences of the ideal curriculum. Moreover, when teachers use the units in their classroom, it gives teachers to possibility to explore the practical consequences of the curriculum innovation, and provides an opportunity to deepen their perceptions and opinions about this innovation. From this point of view, teaching one of the available innovative units is considered a fruitful preparation for understanding and acknowledging the use of contexts in chemistry education when designing an innovative curriculum (goal i).

Organising reflection on practical experiences

Professional development does not only take place by acquiring practical teaching experiences with innovative units. Increasingly, organising reflection is seen as a powerful strategy to promote professional development amongst teachers (Korthagen, Kessels, Koster, Lagerwerf & Wubbels, 2001). Reflection on teaching is a critical examination of one's own beliefs and behaviour in a specific teaching situation; viewing the situation from a different perspective ('reframing', Schön, 1987) with the aim to improve understanding of the situation, and to develop new behavioural and mental alternatives. Based upon the actual experiences in the classroom, the teachers can be stimulated to indulge in theories about underlying teaching and designing principles of a new curriculum (towards goal ii). Korthagen et al. (2001) propose a cyclical process which consists of acquiring experience, looking back, formulating essential aspects, designing alternatives and choosing and trying an alternative. Within this cycle, it is important that the teacher is able to look back on his acquired experiences in such a way that it is visible and understandable for others. Experiences can be written down using narratives, anecdotes and metaphors, and supported by pictures and videos (Van den Berg, Wallace & Pedretti, 2008). Reflection on teaching the available innovative curriculum units can provide teachers with a first perspective on their role to design such context-based units themselves.

Stimulating collaboration with peers

Next to the use of innovative units and the reflection on teaching, collaboration between teachers also contributes to their professional development. Collaboration can consist of discussion, exchange of ideas and experiences, and giving practical feedback (Van Driel et al., 2001; Loucks-Horsley et al., 2003). Moreover, Darling-Hammond and McLaughlin (1995) state that professional development through reflection cannot be accomplished in isolation.

There are many ways to stimulate and organise collaboration between teachers, *e.g.* networks, institutes, courses or workshops. Networks are more or less formalised structures in which participants from different schools aim to achieve previously formulated objectives for a particular period of time. Networks, or learning communities, can range from a very loose structure where teachers meet occasionally and discuss topics of common interest, to more formalised arrangements in which network meetings are led by a supervisor and have predetermined arrangements and goals (Lieberman & Grolnick, 1999; Burbank & Kauchak, 2003, Lumpe, 2007). Institutes, courses and workshops usually occur outside the teachers' classrooms, and bring together educators from different locations for common experiences and learning. Usually led by an external (expert) supervisor or facilitator, these arrangements provide opportunities for participants to focus intensively of topics of interest for several weeks (institutes) (Yerrick, Parke & Nugent, 1997), or for even longer (courses) (Luft, 2001). Workshops tend to be offered over a brief period and address more specific learning goals, such as learning to use a particular set of lessons, or try a new way of assessment. Workshops are characterised by hands-on activities for participants to help them to enact ideas and units (Van Driel, Verloop & De Vos, 1998). Additionally, in designing courses it is advocated to integrate workshop-like activities with classroom practice (De Jong, Veal & Van Driel, 2002). When considering the goals for our study on professional development we are likely to choose a more course-like approach to teacher collaboration.

Organising the design of innovative units by teachers

According to Loucks-Horsley et al. (2003), the design of innovative curriculum units stimulates teachers to expand their content knowledge and pedagogical content knowledge. These authors also stressed the importance of working with a group of teachers to enhance teachers' ability to work collaboratively. There should be sufficient time for reflection on the process of the curriculum design task. In addition, Guskey (2000) showed that it is important that all teachers should have access to relevant information and expertise during the design process to enable them to make well informed and argued decisions. Designing innovative units contributes to teacher empowerment. As noted by George and Lubben (2002), teacher empowerment as a result of curriculum design activities by teachers is a threefold growth: growth in teachers' knowledge and understanding of the innovation, growth in the extent of the acceptance of the characteristics of the innovation, and growth in teachers' confidence as curriculum innovators and decision makers. The strategy to arrange that teachers design innovative context-based units requires that teachers understand the nature of context-based teaching (goal i), prepares the teachers for acquiring the abilities to design innovative context-based units (goal ii), and must make them feel confident about their role to design these units (goal iii). Their confidence grows when they perceive that they are involved in the decision making process, perceive autonomy when giving content to the innovation, perceive that they are provided with a situation that allows them to grow professionally, and increase their self-efficacy.

Empirical studies on professional development programmes

To assess how these strategies are specified and framed into professional development programmes (research question 3), an informed selection of empirical studies is discussed. These studies focus on the design and evaluation of specific professional programmes for experienced science teachers. The studies incorporated the strategies for professional development as discussed in the previous section. In addition, these studies focus on either teaching an innovative unit (Yerrick et al., 1997; Van Driel et al, 1998; Luft, 2001), or on designing an innovative unit (Deketelaere & Kelchtermans, 1996; Parke & Coble, 1997; George & Lubben, 2002). Each study is described with the aim of the study, the design of the programme for professional development, the research focus and data analysis, the results and implications for professional development. References to the four strategies in the descriptions of these studies are highlighted in italics.

Teaching an innovative unit

Yerrick et al. (1997) investigated the influence of teachers' beliefs on the way they interpret a new inquiry-oriented science curriculum. In a two-week summer programme a group of twenty-four middle-grade science teachers with an average of eight years of teaching experience *collaboratively* studied an inquiry-oriented science curriculum. The programme started with articulating the teachers' beliefs about teaching and learning. Next, teachers analysed inquiry-oriented lessons (*providing access to innovative units*), and compared the lessons with tenets of inquiry-based reform and the research papers on teaching and learning. Subsequently, their personal beliefs about teaching and learning were discussed again. Next, inquiry-oriented lessons that illustrate concept connections, collaborative learning, probing questions and student/ teacher dialogue were analysed (*providing access to innovative units*). After that, teachers redesigned their personal lessons to reflect (*organising reflection*) on the reform tenets and the research base. Subsequently, during a whole group discussion the teachers shared ideas and reflected about their personal learning. The authors investigated the influence of this reform effort on teachers' beliefs by interviewing the teachers before and after the programme. They reported a change in teachers' talk about students and content after the programme. However, the authors noted that the observed changes did not imply a departure from past beliefs of teaching and learning. They concluded that a two-week summer programme away from students, schools, and practice did little in-and-of-itself to accomplish change in 'deeply rooted' teacher beliefs. The authors did not connect specific strategies from their programme to the changes in teachers' beliefs. They only considered their programme as a whole. As implications of their study, the authors recommend working with teachers in their daily practice to deal with and think through real dilemma's facing teachers.

Van Driel et al. (1998) focused on developing chemistry teachers' pedagogical content knowledge (PCK). To enhance chemistry teachers' PCK on teaching chemical equilibrium, the authors designed an in-service workshop consisting of several meetings in which an *innovative unit* about chemical equilibrium was presented to twelve experienced chemistry teachers. At the first meeting the participants performed and discussed chemical experiments and assignments from current chemistry textbooks (*stimulating collaboration*). They were asked to react to authentic student responses. The following two meetings coincided with the implementation of the innovative units, and were used to both discuss recent practical experiences as well as to prepare participants for teaching topics following shortly after the meeting. A final meeting was *organised to reflect* on the use of the units in practice. In this meeting, teachers exchanged and discussed their personal experiences and were presented with specific results of the research. The authors audio-taped the workshop meetings, and described the development of the teachers' PCK based on exemplary transcripts of discussions between teachers and one of the authors. In the discussion of their results, the authors wrote that "*this description [of the development of PCK] is constructed by the researchers through a synthesis of the research results with respect to individual teachers and students*" (Van Driel et al., 1998, p. 689). The authors identified several strategies that contributed to the development of teachers PCK about chemical equilibria. These were: teachers should discuss critically texts and experiments from schoolbooks, focusing on specific learning difficulties with chemical equilibria. Next, teachers should discuss examples of authentic students' responses and their own reactions to these examples. Ideally, teachers should then be provided with opportunities to use these teaching strategies in classroom practice. As implications of their study the authors wrote that their series of meetings contributed to resolving a blind spot in teacher in-service education.

Luft (2001) explored how an inquiry-based demonstration classroom in-service programme impacted on the beliefs and practices of a group of fourteen beginning and experienced secondary science teachers. Specific attention was given to (a) changes in behaviours that are conducive to inquiry instruction, (b) changes in beliefs about inquiry instruction, and (c) beliefs about an inquiry-based in-service programme. She designed an

18-month programme which 'attends to the principles of effective professional development,' such as "*creating ample follow-up opportunities for teachers to examine their learning in a new practice*" (Luft, 2001, p. 518). The programme consisted of a one-day workshop that provided an introduction to inquiry-based science instruction in the spring, followed by an extensive five-day workshop during the summer. During this summer workshop participants explored, experienced, and processed an extended inquiry cycle while also designing an extended inquiry cycle to teach in their classrooms (*stimulating collaboration and designing innovative learning activities*). Subsequently, throughout the school year, participants implemented inquiry cycles in their classrooms while they engaged in various types of follow-up activities, such as observing each other's lessons, and meetings in which participants expressed their thoughts about the programme, and discussed and reflected on their practices. With respect to participants' beliefs about the inquiry-based demonstration classroom in-service programme, three emerging trends were visible:

1. participants modified their views about their role in the classroom and about inquiry-based instruction,
2. participants valued the extended inquiry cycles they implemented,
3. participants gained support and assistance during the various follow-up components (Luft, 2001, pp. 528-529).

The author reported that the participants made statistically significant changes in their extended inquiry practices, yet changes in their beliefs were not statistically significant (Luft, 2001, p. 530).). In discussing the results of the study the author limited herself only to effects of the study, and the differences between the beginning and experienced teachers. As implications of this study, Luft wrote that "(...) *in-service programmes should be configured to the diverse population, to the diverse behaviours and beliefs of participants and (...) should contain follow-up experiences with multiple opportunities for interaction*" (Luft, 2001, p. 532).

Designing an innovative unit

Deketelaere and Kelchtermans (1996) described the process of curriculum design as an encounter of different knowledge systems (between teachers and between teachers and supervisors). Their study focused on a group of experienced technology teachers who designed curriculum units that should be more appealing to girls. The authors proposed a model consisting of four phases: (1) a group of teachers, together with a supervisor, create a common platform about the aims and procedures for design and exchange their personal beliefs (*stimulating collaboration*), (2) design and discuss a curriculum unit (*organising the design of innovative activities by teachers*), (3) try the unit in their classrooms, (4) and subsequently modify the unit and discuss their modifications (*organising reflection*). One of the authors (who acted as the supervisor of the group) kept a professional diary. Furthermore, teachers filled in a questionnaire after the curriculum design process, and extensive field notes were made during the group meetings. From their study the authors learned that "*teachers think in terms of actual classroom activities, and appear to have difficulties with moving their thinking to a more abstract level of structure and framework of the module*" and that "*teachers (...) experienced great difficulties operating in vague, ambiguous situation, over which they seem to have no control*", and "*we realised that in curriculum design there is no starting from scratch. Much of the design work includes modification and adaptation of existing materials*." (Deketelaere & Kelchtermans, 1996, p. 76). The design effort had also an effect on the participating teachers in terms of (more) self-esteem, job satisfaction, task perception and subjective educational theory. With respect to changes in teachers' practice, they reported only the use the designed modules (Deketelaere & Kelchtermans, 1996, p. 82). In their conclusions and implications, the authors reported two characteristics that determine success or failure for teachers' collaborative design of curricula. First "*it is necessary to be aware of differences in personal interpretative framework*" (not only between the supervisor and the participants but also between the participants themselves), and second, "*The necessity of becoming aware of the 'subjective' and the 'contextualised' nature of one's personal interpretative framework*" (p.83). This means that teachers and supervisors should take time to explore each others ideas and respect them, and become aware of the subjective and localised nature of each others experiences.

The aim of the study by Parke and Coble (1997) was to empirically test a model for transformational science teaching through which teachers design innovative curriculum units, and change their practice accordingly. Their model consisted of the following phases:

1. teachers share their views about education, their classrooms and their concerns (*stimulating collaboration*),
2. teachers articulate personal beliefs when confronted with ideas from research, such as transformational science teaching (*organising reflection*),

3. teachers design lesson plans consistent with their beliefs (*organising the design of innovative activities by teachers*),
4. teachers align these lesson plans with student diversity and school environment,
5. teachers design assessments,
6. and, subsequently, teachers carry out these lessons plans and assessments in their classrooms.

Parke and Coble (1997) investigated their model by means of an experimental and a control group of students and teachers. Changes in teacher practice were measured using student surveys, teacher beliefs were probed with teacher interviews, and improvement of student learning results were investigated by comparing the results of an achievement test taken by both the experimental and the control group. The authors reported that the experimental students significantly did more experiments, worked more in groups, and enjoyed science more than the control students. However, the standardised tests did not show a significant difference in performance between control and experimental students. From these results they identified several implications for the ongoing professional development of teachers, such as "*past experiences are valuable resources both to themselves and to their colleagues*", and "*curriculum design is a vehicle for both the professional development of teachers and sustained school reform*" (Parke & Coble, 1997, p. 785).

George and Lubben (2002) investigated science teachers' professional growth through their involvement in creating context-based units. They designed and carried out a four day workshop in which twenty science teachers

1. explored context-based sample teaching materials, and brainstormed about relevant contexts for Trinidad and Tobago youngsters (stimulating collaboration),
2. discussed and modified a contextualised lesson plan proposed by one of the facilitators,
3. designed contextualised lesson plans in small teams using the context suggested in the brainstorm session (organising the design of innovative activities by teachers), and
4. discussed these lesson plans in a plenary session (organising reflection).

George and Lubben investigated the participants' pre- and post-workshop perceptions of their role as curriculum designers. About half of the participants saw themselves as contributors to the design process, and the other half saw the benefit of their workshop participation only in terms of obtaining information. Post-workshop questionnaire responses indicated that participants' perceptions of their role did not change much during the course of the workshop. The use of everyday contexts for materials design caused the teachers to reflect on the desired teaching outcomes, and helped them to take responsibility for their practice. This increased responsibility went hand-in-hand with a growing self-confidence. Furthermore, participants reported the encouragement and a new zest for classroom activities resulting from the flexible programme of the workshops. There was a widely supported request for further networking. However, there was one area in which teachers continued to operate as they had done previously. Although teachers focused on making science more relevant to the daily life of students, they were careful to groom students well for the national examinations. Even though there were shifts in orientation to a more student-centred approach as the workshop progressed, the concern about dealing with particular science concepts and preparing students so that they could perform well in school and on examinations always lurked in the background (George & Lubben, 2002, p. 670). In discussing the results of the study, the authors limited themselves to the effects of the workshop as a whole, and on teachers' perceptions of it. They did not draw implications with respect to the design of professional development programmes.

Synthesis of the analysis of the empirical studies

In Yerrick et al. (1997), Van Driel et al. (1998) and Luft (2001) the strategies *providing access to innovative units, stimulating collaboration and reflection*, and elements of the strategy *organising the design of innovative units by teachers* were present. These papers reveal detailed information about collaboration between teachers: the number of participants, the length of the programme, the number of institutional meetings, the inclusion of teaching, *etc*. The first three papers report that the use of *innovative units* and *reflection* were implemented in the designed programme, mostly in this specific sequence. However, information how these strategies were operationalised into the actual teacher activities was scarce. The papers only describe in general terms what teachers did. For example, about reflection Luft (2001) wrote that she organised "*meetings in which participants expressed their concerns of the programme, discussed and reflected on their practices*". Furthermore, Van Driel et al. (1998) wrote that "*a final meeting was organised to reflect on using the teaching/learning materials in practice*." About the use of innovative units, Yerrick et al. (1997) indicated that they asked their teachers to analyse 'inquiry-oriented lessons' and Van Driel et al. (1998) mentioned that they made use of an innovative unit about the topic of chemical equilibrium, which teachers taught in their classrooms.

Deketelare and Keltchermans (1996), Parke and Coble (1997) and George and Lubben (2002) gave us insight into how curriculum design projects could be organised. Some of the other strategies (*stimulating collaboration and reflection*) were present as well. All three studies provided more or less similar general characteristics or approaches for collaborative teacher-based curriculum design. This can be summarised in *five events* for a professional development programme in the following sequence. A group of teachers, together with a supervisor:

- create a common platform about the aims and procedures for design by exchanging their personal beliefs, and about the nature of the curriculum units to be designed,
- design and discuss innovative units,
- enact these units in their classrooms,
- reflect on their classrooms experiences, and modify the units accordingly and
- reflect on the curriculum innovation process.

From the results of these three studies, it appears that teachers appreciated working collaboratively, and felt empowered by the design experience (*organising the design of innovative activities by teachers*). These studies show that this strategy needs to be combined with the three other strategies for professional development, in order to become a strategy for professional development in itself.

Although all the studies provided detailed accounts of the effects of their programmes, the way the strategies for professional development were transformed into specific activities within an professional development programme remains unclear. Furthermore, the studies did not address the relation between these specific activities and the intended and realised teacher learning outcomes of these programmes. Also, empirical relations between the strategies and these intended and realised learning outcomes were not made explicit. Finally, underlying mechanisms between strategies and outcomes as a theory for teacher learning were not made explicit.

Conclusions and discussion

In this paper we focused on three research questions. The first research question looked at the goals of the programmes: What are the goals of a professional development programmes directed at context-based and teacher-based curriculum innovations? We found that for empowering at least a substantial group of leading teachers that take up an active role in a context-based and teacher-based curriculum innovation, the goals for a professional development programme should be:

Goal i: The teachers understand the use of contexts in *teaching* chemistry.

Goal ii: The teachers are able to apply the knowledge about contexts when *designing* new context-based units.

Goal iii: The teachers feel *confident* about their role as designers of context-based units.

The second research question looked at general strategies and type of activities to attain these goals: What type of strategies and activities can be identified in these professional development programmes? We identified four general strategies: *providing access to innovative units* and providing opportunities to practise with these units, *organising reflection* on practical experiences, *stimulating collaboration* with peers, coaches and supervisors, and *organising the design of innovative units by teachers*. It appeared relevant to define, based on these strategies, a teaching and a design strand for a professional development programme. From six empirical studies we found that these four strategies can be framed in the following *sequence of events*. A group of teachers together with a supervisor should:

- create a common platform about the aims and procedures for design by exchanging their personal beliefs, and about the nature of the curriculum units to be designed,
- design and discuss innovative units,
- enact these units in their classrooms,
- reflect on their classrooms experiences, and modify the units accordingly and
- reflect on the curriculum innovation process.

The third research question was: what are the relations between the goals of these programmes and the strategies and activities in these programmes? To answer this question, we used a selection of the literature to specify strategies for teacher-based curriculum innovation and professional development. We concluded that in the empirical literature about teacher-based curriculum innovation and professional development, most studies focus their evaluation on the learning outcomes of the professional development programme. The evaluation of the quality of the actual learning activities seemed to receive little attention. We attributed this lack of attention in empirical research literature for the professional development process to the absence of an underlying coherent description of teacher learning.

This points to the need for further research about teachers' professional development. The research should focus on specifying the relations between the types activities as incorporated strategies for a programme for professional development and the intended learning outcomes, including an explicit mechanism or theories that describe how and why the learning effects can be realised. This result should lead to a further exploration on teacher learning as an underlying theory in order to make the principles for professional development in teacher-based curriculum innovation explicit. This will be the focus in another paper (see Chapter 3). Furthermore, empirical studies are needed in order to investigate whether this provides a suitable starting point for the design of a programme that empowers chemistry teachers to design an innovative context-based chemistry curriculum. The designed programme is one of the results of these design activities.

Our survey of literature was not exhaustive, but we considered the selected studies to be representative of teacher-based curriculum innovation and professional development. Recent studies on the subject (for example, Fishman, Marx, Best & Tal, 2003; Erickson, Minnes Brandes, Mitchell & Mitchell, 2005; Jeanpierre, Oberhauser & Freeman, 2005) do not change our results or conclusions significantly. With the results from this study we expect to contribute to an understanding of effective principles for the design and evaluation of domain-specific professional development programmes with sufficient quality. We also expect that these outcomes also will contribute to improving professional development connected to other national and international science curriculum innovations, context-based or otherwise.

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	Chapter 1 **Introduction and overview** General research question: What constitutes a professional development framework for designing and evaluating a programme to empower teachers for context-based chemistry education?
First Research Cycle	**Chapter 2** **Towards a professional development framework: Goals, strategies and rationale** In this chapter the goals and strategies are presented for a professional development framework for designing and evaluating a programme to empower chemistry teachers for context-based education.
	Chapter 3 **Towards a professional development framework: Learning theory and synthesis** This chapter describes the synthesis of a learning theory, goals and strategies in a framework for professional development to empower chemistry teachers for context-based education.
	Chapter 4 **Evaluation of a professional development framework to empower chemistry teachers for context-based education** This chapter describes an elaboration of the framework into a programme for professional development. The enactment and evaluation of the programme with a group of experienced chemistry teachers are presented.
Second Research Cycle	**Chapter 5** **Evaluating a refined professional development framework to empower chemistry teachers for context-based education** This chapter considers the refined framework and its elaboration into a new programme. The enactment and evaluation of the new programme with a new group of experienced chemistry teachers are described.
	Chapter 6 **Conclusions and reflection** This chapter summarises all major findings and conclusions of the study. It reflects on the both the findings and the research method.

Chapter 3

Towards a professional development framework: Learning theory and synthesis

This chapter describes the second step in the synthesis of the professional development framework, identification of an appropriate learning theory and synthesis. First, teachers' involvement, their concerns and their professional development in several context-based curriculum innovations is discussed. Second, using the goals, strategies and events from Chapter 2, a suitable learning theory is selected. This theory, based on Galperin theory for the internalisation of mental actions, is synthesised with the strategies and goals into a framework that could be a tool for designing a programme and for investigating the professional development processes that take place during the enactment of the programme. It is concluded that empirical research with the framework is necessary.

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Towards a framework for a professional development programme: Empowering teachers for context-based chemistry education

Abstract

The aim of this study is to develop a framework for professional development programmes that empowers chemistry teachers to teach and design context-based chemistry curricula. Firstly, teachers' involvement, their concerns and their professional development in several context-based curriculum innovations is discussed. Secondly, to develop such a framework, a theory for (teacher) learning is needed. From an overview of several theories for (teacher) learning, an adapted version of Galperin's theory for the internalisation of mental actions is selected. Thirdly, this theory is combined with four strategies for professional development, five events for teacher-based curriculum design, and specific goals into a framework for this kind of professional development programmes. This framework will contribute to a better understanding of the relations between the goals of such professional development programmes and, the intended learning processes of the teachers and the sequence of events in such programmes. Empirical research with this framework is recommended.

Aim and outline

Increasingly, teachers actively participate in curriculum change. Instead of carrying out an externally developed curriculum, teachers become involved in design and implementation of new curricula (cf. Clandinin & Connelly, 1992). However, teachers generally do not have experience with curriculum design, and they do not consider themselves as designers (Eisenhart, Cuthbert, Shrum & Herding, 1988; Bencze & Hodson, 1999). Next to changes in subject matter and pedagogy, teacher-based curriculum innovation also involves a change in the way the teachers view their own role in the innovation of curricula. In order to empower teachers to actively engage in curriculum design, appropriate professional development is required.

In a previous study (Chapter 2) we concluded that, to empower chemistry teachers to design a context-based curriculum, several goals need to be accomplished. To attain these goals we identified four general strategies for professional development and we concluded that these four strategies could be framed in a specific sequence of events, see Figure 1. Furthermore, in Chapter 2 we concluded that, although many empirical studies have been published about teacher professional development and teacher learning (*e.g.* Putnam & Borko, 2000; Hewson, 2007), there is little empirical evidence for the *actual activities* in professional development programmes in relation to the *intended and realised learning outcomes* of these programmes. We attributed this lack of attention to the learning process in professional development to the absence of an underlying coherent description of teacher learning. However, professional development strategies should be supported with and combined with a theory for (teacher) learning in order to design effective professional development programmes. The aim of this paper is to contribute to an instructional theory, in which strategies for professional development are related to teacher learning, *i.e.* empowering teachers to design context-based chemistry education. To accomplish this we shall address the following research questions:

- Which learning theory provides principles for teacher learning in professional development programmes that aim at empowering teachers to design context-based chemistry education?
- What framework for these professional development programmes is an adequate synthesis of goals, strategies, events and learning theory?

To answer these, we first describe the innovation and implementation of several context-based chemistry and physics curricula. Subsequently, we describe theoretical notions on teacher knowledge, beliefs and concerns, and present a brief overview of several contemporary perspectives on learning. Next, we discuss the usefulness of these notions and perspectives in terms of the strategies, events and goals for teacher empowerment. Finally, we synthesize the goals, strategies, events and learning theory into a coherent professional development framework. See Figure 1 for an overview of the research presented in this paper.

Goals for professional development:	Strategies for professional development:
Empowerment for teacher-based and context-based chemistry education. i. The teachers understand the use of contexts in teaching chemistry. ii. The teachers are able to apply the knowledge about contexts when designing new context-based units. iii. The teachers feel confident about their role as designers of context-based units.	- Providing access to innovative units. - Organising reflection on practical experiences - Stimulating collaboration with peers - Organising the design of innovative units by teachers. Empirical evidence: Sequence of events for teacher-based curriculum design. No empirical evidence: Relations between intended outcomes and professional development activities.
Framework for professional development: - Two strands for professional development (teaching and designing). - Instructional theory for learning in phases (Galperin's theory for learning). - Defining orienting bases and orienting charts for both teaching and designing (Galperin's theory for learning).	

Figure 1: Overview of the research presented in this paper. The research focuses on learning theory and the synthesis of goals, strategies and learning theory into a framework for professional development.

Following Reigeluth (1987) and McKenney, Nieveen, & Van den Akker (2006), this paper uses specific definitions for (*instructional*) *model*, *strategy* and *principle*. The term *strategy* refers to a sequence in which stages or activities in a programme are executed or planned. A strategy can be a combination of strategy components. For the combination or synthesis of a number of strategies, the word *framework* is used for a professional development programme (for teacher learning). *Model* is used for a unit of a context-based programme (for students learning). Both *framework* and *model* can be considered as a synthesis of principles. However, to avoid confusion the texts below make a distinction between a synthesis of principles into a framework for teacher learning and a synthesis of principles for student learning. The term *descriptive principle* is used for the combination of a strategy (component) and its intended effects/outcomes. A *prescriptive principle* identifies the strategy (components) that should be used for a given intended effect/outcome and, related condition(s). A principle is driven by an underlying *mechanism* (theory for learning) that relates the chosen *strategy* (component) to the intended learning outcomes. The intended learning outcome may be *reaching a higher level of abstraction to understand the teachers' classroom experiences*. Furthermore, in this paper the terms '*design*' and '*development*' are used in the following way. The term '*design*' is used to describe the activities of generating a (unit of a) programme for students or teachers. The activities range from generating the idea for a unit to the writing of the details that are needed for teaching and learning (including the details of the curriculum units). The designed programme is one of the results of these design activities. The term '*development*' is used in 'professional development programme' of teachers. This paper focuses on the professional development of teachers, not on the activities of students in a unit or a programme.

Context-based curriculum innovation

Traditionally, science is presented as a rigid body of facts, theories and rules to be memorised and practiced (De Vos, Bulte & Pilot, 2002). Research has shown that students are not motivated by this kind of science education (Osborne & Collins, 2001), and that the traditional science curricula have become isolated from society, chemistry itself, and the learner (Van Berkel, De Vos, Verdonk & Pilot, 2000). In an attempt to address these problems, many context-based curriculum innovations have been initiated. These projects started in the 1970s with the Dutch Physics Education Project (PLON), followed by the British Salters' Advanced Chemistry (SAC) and the American Chemistry in Context (CiC) (Kortland, 2005; Bennett & Lubben, 2006; Schwartz, 2006). More recently, the German Chemie in Kontext project (ChiK) (Parchmann, Gräsel, Baer, Demuth & Ralle, 2006) and the Dutch New Chemistry project (NC) (Driessen & Meinema, 2003). These innovation projects differed in scale and scope, but shared some common characteristics with respect to the nature of the reform:

- There is a strong emphasis on active involvement of students in their own learning processes.
- All context-based programmes start with introducing a context for students that should raise their curiosity.
- Contexts are used for inducing meaning for students and a 'need to know', justifying the science concepts to be learned.

Although the meaning of 'context' in the different innovations is based on different theoretical frameworks (Waddington, 2005), these characteristics are in accordance with Gilbert's analysis on context-based chemistry education (Gilbert, 2006). For the purposes of this paper, a context-based approach is defined by these characteristics. These characteristics imply not only a change in subject matter, but also a change in teachers' pedagogy. Changing pedagogy requires appropriate implementation.

Context-based curriculum implementation

Large-scale implementation of a new curriculum is considered a difficult and risky endeavour. It is widely recognised that teachers play a crucial role in innovations (Fullan, 2007). The involvement of teachers, their concerns, and their professional development can foster or hinder the implementation of a context-based science curriculum considerably (Altrichter, 2005; Pilot & Bulte, 2006). In discussing curriculum implementation strategies, we will address the abovementioned context-based innovation projects, and relate these projects to notions from the literature.

Teacher involvement

Major large-scale context-based reforms initiated in the 70s and 80s, such as PLON, SAC and CiC, roughly followed a model of research, development and dissemination (RDD). The research and development were carried out by a small group of curriculum experts and policymakers, whereas schools and teachers were expected to implement the prescribed curriculum, adapting the newly developed teaching materials to fit with their local circumstances (Campbell et al., 1994; Budd Rowe, Montgomery, Midling & Keating, 1997; Kortland, 2005; Waddington, 2005). The RDD model was rather successfully used in SAC and CiC, which were both nationally implemented, whereas PLON was only implemented regionally, and for a limited period of time. Kortland (2005) attributes this limited success to a lack of publicity during the research and development phases; teachers felt overwhelmed when they were confronted with fully developed PLON materials. Although the teachers were not involved in the initial phases of the innovation, Salters and CiC became very successful, and were implemented on a national scale (Bennett & Lubben, 2006; Schwartz, 2006). Recently, a more teacher-centred approach was initiated in both ChiK and NC. In this approach, a core team of curriculum experts developed prototypical units and (one or more) curricular frameworks. Subsequently, groups of interested teachers used the framework(s) by developing, field-testing and revising the unit materials. After these initial groups, teachers (should) start their own groups, developing the existing materials further, or design new modules. Although the implementation of both reform projects is at an early stage, ChiK teachers consider their freedom of choice of topics and activities the most important factor for a successful implementation (Eilks, Parchmann, Gräsel & Ralle, 2004). There are indications that this kind of teacher involvement fosters the implementation of this reform. Next to the abovementioned approaches, there are other ways to involve teachers in curriculum innovations, like participatory action research (Eilks & Ralle, 2002; Eilks, 2007) or teacher study groups (Shwartz, Ben-Zvi & Hofstein, 2005). Although these initiatives have similar objectives, they are limited in their range. For the purpose of this paper, we focussed our discussion on large-scale (state and nation-wide) context-based curriculum innovations.

Teacher concerns

Although most teachers support the nature of the reform projects, the literature reports a variety of curricular concerns. Teachers express concerns for the quality of the subject matter. They fear that subject matter is going to be diminished or they will have, owing to new contexts, less class time available to cover the content of the curriculum (Bennet, Gräsel, Parchmann & Waddington, 2005; Coenders, Terlouw & Dijkstra, 2008). This concern for subject matter was emphasised in the results from a questionnaire sent to 966 Dutch Chemistry teachers. Van Driel, Bulte & Verloop (2005) reported that teachers strongly support teaching of traditional chemistry. However, in the same survey, they almost equally supported a context-based approach towards chemistry, in which students learn to communicate and make decisions about social issues involving chemical aspects. Next, they look at the consequences for their teaching practice. Context-based reforms also include a change in pedagogy. Actively involving students in their own learning processes requires a shift from a transmissional to a more transformational mode of teaching (Keys & Bryan, 2001). Van Driel et al. (2005) wrote that teachers in their survey also expressed considerable support for a curriculum that pays attention to the nature of chemical knowledge as something that constantly develops in a social-cultural context. The Dutch chemistry teachers interviewed by

Coenders et al. (2008) indicated that they want to incorporate activities which foster reflection on the learning process and learning results into the new curriculum. From a survey conducted among 222 experienced SAC teachers Bennett et al. (2005) reported that these teachers felt their students were better able to engage in independent study and take more responsibility towards their own learning. Thirdly, teachers' new role as designer of new context-based teaching materials was considered. Although nearly all teachers have developed some kind of teaching materials, they generally do not regard themselves as designers of new and innovative materials (Eisenhart et al., 1988). However, Coenders et al. (2008) reported that Dutch chemistry teachers who are already engaged in the development of comprehensive learning materials perceived it to be very rewarding. Since designing is generally a collaborative effort, German ChiK participants indicated that they value highly the cooperation in and support from their learning communities when developing and evaluating new context-based materials (Eilks et al., 2004). Teachers' curricular concerns need to be taken into account during the development and implementation of a curriculum innovation (Gail Jones & Carter, 2007). It appears that abovementioned context-based reform projects positively connect with the teachers' reported concerns, and that these concerns can foster the implementation of new context-based curricula.

Professional development

All the above mentioned reform projects indicate that they consider teacher professional development an issue that is difficult to address. In their analysis on the implementation of SAC and CiC, Pilot and Bulte (2006) concluded that despite teachers' initial enthusiasm, their traditional practices about chemistry education were very difficult to change. Professional development in SAC and CiC consisted mainly of workshops and seminars to train teachers to be able to work with the context-based teaching materials. Although data on teacher professional development in both ChiK and NC is limited, the support ChiK teachers received from their learning communities was reported as a factor that influenced strongly the changes to their teaching strategies (Eilks et al., 2004). While SAC and CiC focused teachers' professional development on changing their knowledge and skills, ChiK and NC appear to acknowledge the multi-faceted nature of teacher professional growth (Clarke & Hollingsworth, 2002), addressing teachers' knowledge, beliefs, attitudes and concerns. There is a growing consensus in the literature that for a successful reform, instead of emphasizing gaps in teachers' skills, their knowledge, beliefs, attitudes and concerns needed to be included in the development and implementation of a new curriculum (Van Driel, Beijaard & Verloop, 2001; Davis, 2003; Gail Jones & Carter, 2007; Abell, 2007).

A theory for teacher learning

Teacher knowledge, beliefs and concerns

Teachers' knowledge can be described in several categories, including subject matter knowledge, knowledge of contexts, pedagogical knowledge and pedagogical content knowledge (PCK). PCK was initially described by Shulman (1987, p. 8) as "that special amalgam of content and pedagogy"; it is the knowledge of teachers to help others to learn the content. Within a teachers' knowledge base, PCK is considered to play a central role (Magnusson, Krajcik & Borko, 1999; De Jong, Van Driel & Verloop, 2005). Development of a teachers' knowledge base starts during formal teacher education. When teachers acquire more teaching experience, this knowledge base modifies and expands. These changes to the teachers' knowledge base enrich all types of knowledge, but especially their PCK. Experienced science teachers convey more PCK than their beginning counterparts, and their PCK is firmly integrated in their knowledge base and beliefs (Loughran, Mulhall, & Berry, 2004; De Jong et al., 2005). However, due to its tacit and situated nature, teachers' PCK is difficult to assess and also hard to change (Abell, 2007).

Beliefs are important in the development of teachers' knowledge base. Beliefs act like a filter through which new knowledge is interpreted, and subsequently integrated into the knowledge base. Beliefs play a central role in organizing knowledge and defining behaviour and influence almost every aspect of teaching (Calderhead, 1996; Van Driel et al., 2001). Teacher beliefs tend to be relatively stable and resistant to change; this is particularly true for experienced teachers (Gail Jones & Carter, 2007). For example, Luft (2001) found that an in-service program designed to promote inquiry teaching resulted in a change in practices but not in the beliefs of the teachers. Furthermore, Peers, Diezmann & Waters (2003) have shown that the time required to understand an innovation and to reflect on it and make changes to teaching practice is one of teachers' most significant concerns. Teachers with strong self-efficacy beliefs seemed to be more prepared to experiment with, and later to implement, new educational practices (Haney, Lumpe, Czerniak & Egan, 2002). This view is supported by the finding that the way teachers react to a reform is largely determined by whether or not teachers perceive their professional identities as being reinforced or threatened by the reform (Van Veen & Sleegers, 2006). The dimension of self-efficacy beliefs is one of the dimensions of teacher empowerment (Chapter 2), that is considered an important goal of both personal and professional growth (Short and Rinehart, 1992; Bell & Gilbert, 1996).

Perspectives on learning processes

Although the above mentioned notions about teacher knowledge and beliefs need to be taken into account when designing a professional development programme, they do not offer a concise theoretical description of teachers' learning process during a professional development programme (intended learning process). Without such a description only the goals of a programme can be evaluated and not the way through which these goals were accomplished (realised learning process). Comparison of the intended and realised learning process contributes to a better understanding of how to design teacher professional development programmes (Chapter 2). As mentioned in the introduction, one of the goals of this paper is to look for a theory, which provides a concise description of a professional development process. Therefore, we will briefly discuss several perspectives on learning processes, the cognitive perspective, the social cultural perspective and the participatory perspective (Scott, Asoko, & Leach, 2007).

Cognitive perspectives on learning had a major influence on science education since the early 1980s (Driver, Asoko, Leach, Mortimer & Scott, 1994). Within cognitive epistemology, learning was initially viewed as development and change in conceptual understanding. Conceptual development takes place by means of assimilation, accommodation, and equilibration. A new concept can be incorporated into an existing structure of concepts, without altering the structure (assimilation), whereas accommodation requires a change in the structure for a new concept to be incorporated (Piaget, 1952; Kitchener, 1992). Because of the assimilation and accommodation, the conceptual structures become more and more complex. For conceptual development a constant balancing is needed between assimilation and accommodation, called equilibration. Posner, Strike, Hewson & Gertzog (1982) extended this theory by incorporating conditions for conceptual development: learners must be dissatisfied with existing conceptions, and they must acknowledge the intelligibility, plausibility and fruitfulness of a new concept. Later, Strike and Posner (1992) reformulated some aspects of their theory, adding the influence of existing concepts on conceptual change to their theory. Pintrich, Marx, & Boyle (1993) criticised this 'cold conceptual change theory' and stated that motivational and contextual factors must be taken into account, as the individual learner is subjected to influences from its social setting.

In the cognitive perspective, learning is also considered as an active process, in which students actively construct their own knowledge. In order for students to actively construct their own knowledge, teachers can no longer adhere to their traditional role of transmitting knowledge. If teachers are assumed to learn essentially in the same way as students do, teachers also have to construct their own knowledge and direct their own learning. Consequently, teachers must be supported to acquire this new knowledge and beliefs, and specific attention has to be paid to support the change in their existing knowledge and beliefs. Learning by teachers has to be facilitated by creating favorable learning environments in which teachers take charge of their own learning (Loucks-Horsley, Love, Stiles, Mundry & Hewson, 2003; Peers et al., 2003).

The social cultural perspective on learning was introduced by Vygotksy and elaborated further by, amongst others, Galperin (Vygotsky, 1978; Galperin, 1992; Arievitch & Haenen, 2005). Vygotsky investigated how children's mental functions developed through social interactions. Through these interactions, a child learns the habits of mind of her/his culture, including speech patterns and written language. This process is known as internalisation, which can be understood as 'knowing how'. The mastery of these skills occurs through the activity of the child within society. A further aspect of internalisation is appropriation, in which the child takes a tool and makes it his own, perhaps using it in a way unique to himself. The process of internalisation is carried out through social interactions, for example, with an adult. A child follows the adult's example and gradually develops the ability to perform certain actions without help or assistance. The difference between what a child can do with help and what he or she can do without guidance is called the zone of proximal development (ZPD) (Vygotksy, 1978).

Galperin's research focused on how human mental activity is formed out of the transformation of 'external' activity. Galperin's research focused on how to guide the process of internalisation of a new activity by an individual. Rather than passively observing the emergence of a new psychological process, Galperin investigated the internalization of a new activity in carefully designed experiments. Thereby he disagreed with Piaget on the relevance of the observation method (Arievitch & Haenen, 2005). According to Galperin, learning of any kind of knowledge is the gradually increasing mastery of actions. From his studies he conceptualised internalisation as a transformation of certain (material) forms of individual external activity into other (mental) forms of that same activity, and as a specifically human form of appropriation of new knowledge and skills. In his theory, Galperin integrated the learning of declarative knowledge (the acquisition of rules and facts) with procedural knowledge (the 'application' of those rules and facts) (Arievitch & Haenen, 2005). The concept of 'action' has to be very broadly conceived as conscious attempts to change objects according to some intended result, with three basic levels of abstraction, related to the form of the action: the material, verbal and mental level, for example, drawing a triangle, proving Pythagoras' theorem, and recognising a pattern.

Another key idea in Galperin's theory is the concept of 'orienting basis for an action'. It refers to the whole set of elements on which the learner is orienting him/herself along the execution of an action. The form of an action, including the generalisation and abbreviation, should gradually change during the course of the learning process. The purpose of the *orienting chart* in this process is that the conceptual scheme of it is internalised, and so becomes a mental model for the orientation on the action. Galperin distinguishes the phases in this theory for learning and instruction (for a more elaborate discussion, see Haenen, 2001):

1. Orientation on action.
2. Performance of action.
3. Reflection on the performance.

During the 'orientation on action', the learner is provided with all the information necessary for the correct execution of a new action. The information includes the intended outcome, objects and means of the action, and the necessary steps and conditions of action. This information is put together in an 'orienting chart'. This orienting chart needs to be as complete as possible to create a complete orienting basis that is needed to perform an action correctly. Furthermore, when the orienting chart is a meaningful whole, it supports motivation for learning. The orienting chart therefore serves as the main tool of learners' orientation on the key elements for an action or the sequence of actions (Galperin, 1992; Haenen, 2001; Arievitch & Haenen, 2005).

Several studies provided evidence for the success of this theory and such orientating charts, *e.g.* in domains such as handwriting, calculus, language and thermodynamics (cf. Haenen, 2001; Karpov, 2003). However, regarding the strategy component 'providing a complete orienting basis', several researchers argued that for more complex tasks, in which heuristic decisions are involved (such as teaching), orienting bases cannot and should not be made complete at the start of the learning process (Van Oers, 1987; Terlouw, 1993; 2001). They argued that for tasks with heuristic components learners, certainly adult learners, should be provided with an incomplete (preliminary) orienting basis. In a spiral formation of new actions, this (incomplete) orienting basis should provide the learners with a better understanding of the actions, resulting in newly acquired forms of orienting activity. This should give them components of self-regulation such as cognitive planning and monitoring, also related to the aptitude of readiness for learning the new complex task, expanding the zone of proximal development (Arievitch & Haenen, 2005). This design of the learning process with an incomplete orienting basis should give the learner sufficient confidence to perform the action in the second phase of the learning process. In the third phase of the learning process, reflecting on the performance of the action expands the applied orienting basis. Terlouw (1993; 2001) summarised these adaptations to the original theory as follows, see Table 1.

Table 1: Phases from the original and adapted theory.

	Original theory	Adapted theory
1	Orientation on action	Creating a preliminary orienting basis
2	Performance of action	Applying this orienting basis
3	Reflection on the performance	Expanding this orienting basis.

When, after reflection on the execution of an action, the orienting basis is expanded, this orienting basis can act as a preliminary orienting basis for the orientation on a new, more mental, action.

In the participatory perspective, also known as situated cognition, learning is seen as a process of participation in socially organised practices (Brown, Collins & Durguid, 1989). Moreover, knowledge and skills are situated within these practices, social in nature, and distributed across persons and tools (Putnam & Borko, 2000). Within this perspective, learners acquire knowledge and develop skills, by means of cognitive apprenticeship (Rogoff, 1990), or legitimate peripheral participation (Lave & Wenger, 1991). The learner takes the role of apprentice, whereas the teacher is seen as an expert participant. While earning, the responsibility of the learner as a member of a community of practice increases, moving from a peripheral to a more central position. The situated nature of cognition emphasizes the importance of authentic learning activities, which are comparable to what actual practitioners do. With respect to teacher professional development, Putnam and Borko (2000) wrote that experienced teachers mostly acquire their professional knowledge in practice. However, due to the context-bound nature of this knowledge, it is difficult to change this knowledge (and subsequently teacher practice). To address these problems, Putnam and Borko (2000) recommended situating teacher learning in multiple learning settings (in and out of classrooms) in which teacher educators play important roles.

Answering the first research question

The first research question in this paper is: Which learning theory provides principles for teacher learning in professional development programmes that aim at empowering teachers to design context-based chemistry education? We briefly described three contemporary perspectives on learning, the cognitive, the social cultural and the participatory perspective. Since these perspectives originate from different paradigms, they differ substantially in their focus, and their description of the learning process. Despite their differences, these perspectives are viewed as complementary rather than exclusive (Putnam & Borko, 2000; Scott et al., 2007). Which perspective we will use for designing our professional development programme, not only depends on the epistemology of the theory but also on the strategies, goals, and events of the intended professional development process (see Figure 1). Choosing between the perspectives is difficult because there is no objective 'best' perspective for learning. However, with these strategies, goals, and events of our professional development process, we might distinguish between these perspectives in terms of the learning process our teachers have to go through in accomplishing these goals.

Designing an innovative curriculum is an activity teachers rarely carry out. Generally, their activities involve the fine-tuning of the existing curriculum units to the specific situation in the class, and so most teachers do not feel confident with design activities. Therefore, when becoming empowered to design, the teacher should be guided by experts and gradually develop the ability to design and increase their confidence for design activities. Furthermore, designing new curriculum units is usually not an individual effort (cf. Salters' Advanced Chemistry, Chemie im Kontext, Chemistry in Context, PLON). Collaboration between different designers, by means of providing feedback, contributes to the improvement of the quality of the innovative units. From a participatory perspective, the strategies (see Figure 1), can be seen as teachers becoming apprentices in the community of educational designers, guided by expert-practitioners. From a cognitive perspective, teachers' cognitions are likely to become accommodated to incorporate this new knowledge. However, these notions do not bring us closer to a description of the intended learning process.

From a social cultural perspective, designing an innovative curriculum can be seen as a new activity, which is not part of the teachers' mental actions. In this learning process the teacher-learner expands his or her zone of proximal development. Galperin's theory provides strategies for the design of a learning process in this zone in which the learner is developing new actions. As described by Arievitch and Haenen (2005, p. 162) "To *enhance the leaner's potential to learn in the ZPD, Galperin focused on improving the qualities of their orienting activity within their stepwise teaching-learning procedure*." These steps provide explicit guidelines how to guide learners within their zone of proximal development. Therefore, in this intended learning process the learner should follow learning phases with explicit orientation, exploration and guidance by experts before performing the actions without help or assistance, gradually developing the ability to design and subsequently develop confidence for design activities. In this learning process the learner expands his or her zone of proximal development. Galperin's theory provides strategies for the design of a learning process in this zone in which the learner is developing new actions.

The goal of a professional development programme in this study is to empower teachers for the design of context-based units (see Figure 1). From a cognitive perspective, teachers need to experience dissatisfaction with existing chemistry curriculum and their current role, and become aware of the fruitfulness of the context-based approach and their new role as designers of new curriculum units. To become aware of the fruitfulness of the context-based approach, teachers will be asked to teach an existing innovative context-based unit and collaboratively reflect on their experiences. To become aware of the fruitfulness of their role as designers, teachers will be asked to collaboratively design a new, innovative, context-based unit and reflect on their experiences (see Figure 1). From a social cultural perspective, this design task embodies several complex actions, which cannot be mastered within one single step. Next to more self-evident divisions of the actions within the course of the learning process, we have chosen to distinguish two clusters of actions: (1) *teaching* a context-based unit, and (2) *designing* such a unit. Although these two clusters of actions are closely related and have to be integrated at the end of this learning process, we decided to separate them in the design of this learning process. For each cluster of actions an orienting base is needed, but these orienting bases are related. The orienting basis for the actions to teach context-based units, including the use of an underlying general model of context-based education, is conceptualised as an elaborate form of the 'orienting chart' for the actions to design context-based units. In this operationalisation the orienting chart for teaching is 'nested' within the orienting chart for designing. The cognitive perspective and the social cultural perspective are complementary, although the social cultural perspective provides us with more explicit guidelines on how to arrange such learning processes.

To become engaged in a curriculum reform in which teachers develop new context-based curriculum units themselves, teachers require certain knowledge about the nature of the reform, skills to develop these materials, and an improvement in confidence for their new task. A short-time professional development program, which teachers have to follow alongside their full time jobs, cannot turn teachers into full-fledged designers. However, it can provide teachers with an orientation on the new curriculum in terms of knowledge they have to acquire and actions they have to carry during its development and implementation. Our interpretation of the Galperin theory, follows a Putnam and Borko's (2000) recommendation, that teacher learning should be situated in multiple learning settings (in and out of classrooms) in which teacher educators play an important role. Deketelaere and Kelchtermans (1996, p. 83) reported that "*teachers think in terms of actual classroom activities, and appear to have difficulties with moving their thinking to a more abstract level of structure and framework of the curriculum module*." Because teachers are considered to be practitioners, they are most likely to be interested in the practical consequences of an innovation. The intended learning in the planned professional development programme can thus be operationalised by focusing on teaching an innovative context-based unit as an exemplar or key idea of a new curriculum, and subsequently on designing a context-based unit. These two strands are connected through the notion that teaching the unit provides teachers with an orienting basis for design, including knowledge about and motivation for the innovation.

Knowledge and actions are not separated from each other. Acquiring knowledge about, for example, context-based chemistry is closely connected to performing actions like teaching a context-based teaching unit. Looking at the four strategies for professional development we selected (see Figure 1) we consider the intended professional development to be closer to the social cultural perspective, than it is to the cognitive perspective, and the participatory perspective. Therefore, in answering the first research question, we conclude that the social cultural perspective, and more specifically, the adapted theory of Galperin provide a proper theoretical description and explicit guidelines for the professional development process we intend to design and evaluate. Galperin's theory was successfully used by Edwards (1995) to design a framework for pre-service teachers training partnerships between schools and universities, and by Terlouw (2001) to design a school-wide in-service programme for professional development of teachers about the use of information technology in teaching and learning. The three-phase theory alone does not provide sufficient guidelines for designing and evaluating a professional development process. However, when combined with the goals, strategies and events for professional development (see Figure 1), and with practical and theoretical notions on teacher knowledge, beliefs and concerns (see the previous sections), the theory will provide us with a concise description of the professional development process we want.

Towards a framework for professional development

When connecting strategies for professional development (see Figure 1) to the intended learning outcomes (to empower teachers for designing a context-based teaching unit), the three learning phases (1. creating a preliminary orienting basis, 2. applying this orienting basis and 3. expanding this orienting basis) need to be combined with the goals for a professional development programme on context-based chemistry education (See Figure 1):

Goal i: The teachers understand the use of contexts in teaching chemistry.
Goal ii: The teachers are able to apply the knowledge about contexts when designing new context-based units.
Goal iii: The teachers feel confident about their role as designers of context-based units.

This framework should include four general strategies for professional development (Chapter 2): providing access to innovative units and providing opportunities to practise with these units (Ball & Cohen, 1996; Davis & Krajcik, 2005), organising reflection on practical experiences, (Schön, 1987; Korthagen, Kessels, Koster, Lagerwerf & Wubbels, 2001), stimulating collaboration with peers, coaches and supervisors (Loucks-Horsley et al., 2003; Lumpe, 2007) and organising that teachers design innovative units. The framework also should include five events for teacher-based curriculum design: a) create a common platform about aims and procedures for design, b) design and discuss innovative units, c) enact these new units in their classroom, d) reflect on their classroom experiences, and modify the units accordingly, and e) reflect on the process of curriculum innovation (Deketelaere & Kelchtermans, 1996; George & Lubben, 2002).

The teaching of innovative units is considered as a necessary condition for the design of new context-based units (see end of previous section). Empowering teachers for their role in teacher-based curriculum innovation therefore implies the appropriation of two sequential orienting bases: *an orienting basis for teaching* (T) followed by an *orienting basis for designing* (D). The orienting basis for teaching is nested within the orienting basis for designing.

Based on the phases of Galperin's theory of learning, this leads to the following sequence of interrelated phases as a framework for professional development. It consists of six phases, subdivided into two strands of actions: (T) teaching a context-based unit and (D) designing a context-based unit, in which the teaching strand is nested within the design strand (Figure 2; see also the curriculum representations in Chapter 2).

The *orienting basis for teaching* is created through the following three phases:

T1 Motivation and orientation: provide general motivation, and create a preliminary orienting basis for teaching a context-based unit. This phase must create a collaborative platform for exchanging the aims and procedure of the new context-based curriculum design, and the teachers' personal beliefs in relation to their new role in context-based curriculum innovation. A new unit as an exemplar is discussed (event *b*) on the basis of its underlying context-based model. The exemplar unit and its underlying model together form an advanced 'orienting chart'. It must communicate the course of action for designing (and consequently teaching) when the teachers start their professional development programme and are expected to have rather general and not-reflected ideas about contexts and their use in practice. The requirements of new units are specified (events *a* and *b*).

T2 Application: apply this orienting basis. The exemplar unit is used as a try-out in the safe environment of the teachers' classrooms (event *c*).

T3 Reflection: expand the orienting basis for teaching. The teachers reflect on their classroom experiences, and when necessary, they formulate suggestions for modification (event *d*). A collaborative reflection on the opportunities and difficulties of context-based chemistry education as it is shaped in the exemplar unit contributes to the expanding of the orienting basis for teaching.

Consequently, in the first strand an orienting basis for teaching is created. The related mastering of new actions with respect to teaching implies that teachers:

- have acquired an overview how to teach a context-based unit,
- are able to teach a context-based unit,
- feel confident to teach a context-based unit.

When teachers have acquired this orienting basis for teaching, we assume that this is the first step of the second stand: *a preliminary orienting basis for designing* a context-based unit. After the first strand, they have acquired an initial understanding of a general model of the context-based unit (see * in Figure 2).

In the second strand an orienting basis for designing a context-based teaching unit is created. This orienting basis for designing is created through the following three phases:

D1 Motivation and orientation: provide general motivation for designing and create a preliminary orienting basis for designing a context-based unit. This phase is actually composed of the phases T1, T2, and T3. Consequently, the common platform to discuss the newly designed curriculum units has become enriched (an expansion of event *a*).

D2 Application: apply this orienting basis for designing. In this phase, the teachers use their classroom experiences with the exemplar unit, and consequently their knowledge about the underlying context-based model for the design of an outline of an entirely new context-based unit (a further expansion of event *b*). In this phase, the teachers use their 'orienting chart', which has been developed for creating a preliminary orienting basis for designing in the former phases T1, T2 and T3.

D3 Reflection: expand the orienting basis for designing. This phase should be a reflection on the curriculum innovation process (event *e*). But this is not fully possible within the obvious constraint of an introductory programme to empower teachers for teacher-based curriculum innovation. By reflecting on the designed outline, the teachers are expected to explore further the opportunities and difficulties of context-based chemistry education. Their confidence about their role to design (parts of) context-based units should grow when they perceive that they are involved in decision-making, and they have a perception of autonomy, professional growth and self-efficacy.

The related mastering of new actions with respect to designing implies that teachers (see Figure 2):

- have acquired further understanding of a general model of a context-based unit
- are able to design an outline of a new context-based unit,
- feel confident to use a general model of a context-based unit.

When the teachers have acquired the orienting basis for teaching, this can be considered as the first conditional phase to reach goal i (to understand the use of contexts). After having acquired the orienting basis for designing, we expect the teachers to be empowered for their active role in a teacher-based curriculum innovation, that is: they understand the use of contexts (goal i), they can apply knowledge about contexts when designing a unit (goal ii), and they feel confident about their role as

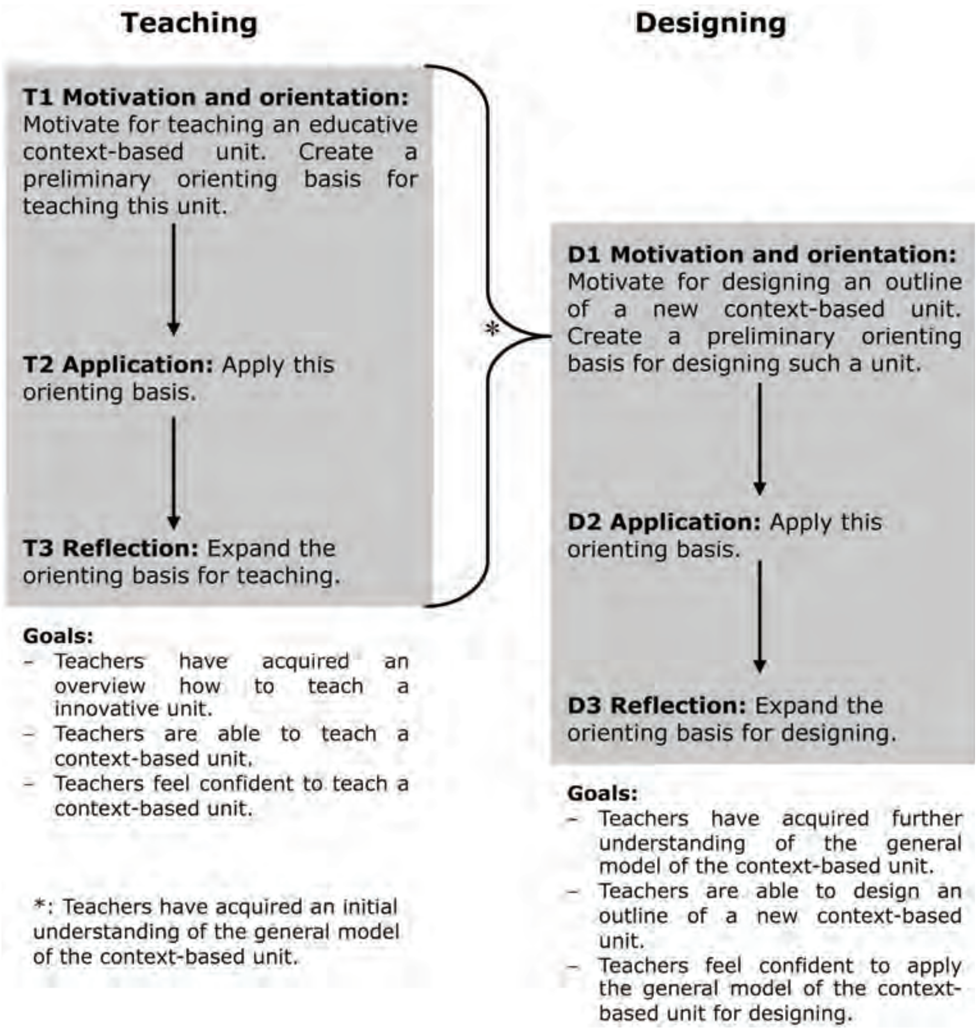

Figure 2: Overview of the professional development framework.

designers (goal iii). It should be noticed that the goals (i–iii) and learning phases (1–3) are not related on a one-to-one basis: goal i is related to phases T1, T2 and T3; goal ii is related to D1, D2 and D3; goal iii is related to all phases. Within the constraints of the teachers' current workload (Loucks-Horsley et al., 2003), an introductory professional development programme cannot turn teachers into full-fledged designers. However, it can provide teachers with a first orientation on the new curriculum in terms of knowledge to acquire and actions to perform during its design and implementation.

The second research question in this paper is: What framework for these professional development programmes is an adequate synthesis of goals, strategies, events and learning theory? In this section we described the framework and provided arguments why this framework can be considered to be an adequate synthesis, supporting teachers from the goals towards attaining the intended learning results. However, our answer is preliminary. To answer this research question more completely, empirical research is necessary, in which the framework is used in designing a professional development programme.

Conclusions and implications

In Chapter 2 we concluded that, although many studies have been published on teacher professional development and teacher learning, there is little empirical evidence for the actual activities in professional development programmes in relation to the intended and realised learning outcomes of these programmes. Therefore, the first research question in this paper was related to this issue: Which learning theory provides principles for teacher learning in professional development programmes that aim at empowering teachers to design context-based chemistry education? We described an adaptation of Galperin's theory of internalisation of actions. This theory provides principles for defining orienting bases and orienting charts for both teaching and designing. It also provides an instructional theory for learning with the phases: orientation in action, performance in action and reflection of action. We conclude that that this theory is suitable to be combined with the previously described goals, strategies and events into a framework for professional development programmes.

With this result it was possible to focus on the second research question: What framework for these professional development programmes is an adequate synthesis of goals, strategies, events and learning theory? We combined the professional development strategies, events for teacher-based curriculum design, and goals for professional development with a theory for (teacher) learning into a framework for professional development of teachers. We described this framework (see Figure 2) and provided arguments why it can be considered to be an adequate synthesis, supporting teachers from the goals towards attaining the intended learning results.

The framework presented in this study has some other characteristics than the frameworks described in a recent review on science teacher professional development (Hewson, 2007). These frameworks focus on changing teacher knowledge and beliefs (Guskey, 2000), changing teachers' practices (Loucks-Horsley et al., 2003) and improving student results (Fishman et al., 2003). Our framework focuses not only on teachers' professional development, but also on their empowerment. It resembles some characteristics of the framework of Bell and Gilbert (1996), in which teacher empowerment is considered as an important part of teacher development. Furthermore, our framework incorporates a description of professional development processes, while such descriptions are not presented in other frameworks. Although we consider these frameworks valuable for describing the complex and multi-facetted nature of teacher professional development, they do not offer a concise theoretical description of teachers' learning process during a professional development programme (intended learning process) within the context of a science curriculum innovation. We consider our framework a first attempt towards such a description (Borko, 2004).

A further study is needed to evaluate whether this framework is a suitable starting point for the design and enactment of a programme, which empowers chemistry teachers to design an innovative context-based chemistry curriculum. To answer this question, design-based research (Lijnse, 1995; McKenney et al., 2006) can be used as research approach. With the framework and the argumentation for strategies and principles as starting point, such an empirical study should focus on the evaluation of enactment of the learning and teaching processes and the attained outcomes. The results of that evaluation can provide a better understanding of the theoretical perspectives that have led to the design of the framework, to adaptations when needed, and to more effective professional development programmes for teachers (see Chapter 4).

Our research programme, outlined above, follows the direction indicated by Hewson (2007, p.1201). He drew the conclusion that "*it is necessary to consider not only the outcomes that the programs seek to achieve but also the means, the processes, the pathways by which these outcomes will be achieved*." Furthermore, Hewson emphasised that "*the likelihood of [professional development] programs being successful is greatly enhanced if these pathways are explicitly included in the program design*." Our programme also includes a comparison of the intended and realised learning process, which will contribute to a better understanding of how to design teacher professional development programmes within context-based and other science curriculum reforms.

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	Chapter 1 **Introduction and overview** General research question: What constitutes a professional development framework for designing and evaluating a programme to empower teachers for context-based chemistry education?
First Research Cycle	**Chapter 2** **Towards a professional development framework: Goals, strategies and rationale** In this chapter the goals and strategies are presented for a professional development framework for designing and evaluating a programme to empower chemistry teachers for context-based education.
	Chapter 3 **Towards a professional development framework: Learning theory and synthesis** This chapter describes the synthesis of a learning theory, goals and strategies in a framework for professional development to empower chemistry teachers for context-based education.
	Chapter 4 **Evaluation of a professional development framework to empower chemistry teachers for context-based education** This chapter describes an elaboration of the framework into a programme for professional development. The enactment and evaluation of the programme with a group of experienced chemistry teachers are presented.
Second Research Cycle	**Chapter 5** **Evaluating a refined professional development framework to empower chemistry teachers for context-based education** This chapter considers the refined framework and its elaboration into a new programme. The enactment and evaluation of the new programme with a new group of experienced chemistry teachers are described.
	Chapter 6 **Conclusions and reflection** This chapter summarises all major findings and conclusions of the study. It reflects on the both the findings and the research method.

Chapter 4

Evaluation of a professional development framework to empower chemistry teachers for context-based education

In this chapter the design, implementation and evaluation of a first version of the programme is described. Based on the professional development framework from chapter 3, a programme to empower chemistry teachers for designing new context-based units was designed. The programme consists of teaching a context-based unit, followed by designing an outline of a new context-based unit. Six experienced chemistry teachers participated in the instructional meetings and practical teaching in their respective classrooms. The findings indicate that teachers became only partially empowered for designing context-based chemistry education, and that the intended professional development process partly did take place. Based on these findings, revisions of the framework and the programme are proposed.

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Exploring a framework for professional development in curriculum innovation: Empowering teachers for designing context-based chemistry education

Abstract

Involving teachers in early stages of context-based curriculum innovations requires a professional development programme that actively engages teachers in the design of new context-based units. This study considers the implementation of a teacher professional development framework aiming to investigate processes of professional development. The framework is based on Galperin's theory of the internalisation of actions and it is operationalised into a professional development programme to empower chemistry teachers for designing new context-based units. The programme consists of the teaching of an educative context-based unit, followed by the designing of an outline of new context-based unit. Six experienced chemistry teachers participated in the instructional meetings and practical teaching in their respective classrooms. Data were obtained from meetings, classroom discussions, and observations. The findings indicated that teachers became only partially empowered for designing a new context-based chemistry unit. Moreover, the process of professional development leading to teachers' empowerment was not carried out as intended. It is concluded that the elaboration of the framework needs improvement. The implications for a new programme are discussed.

Introduction

Designing professional development for science teachers during educational reform is a complex endeavour. Increasingly, design of professional development efforts is guided by frameworks for professional development. These frameworks provide tools for design and evaluation of professional development programmes, like different strategies for professional development or a focus on changes in science teachers' knowledge, beliefs and attitudes, changes in teacher practice, or improvement of student results (Bell & Gilbert 1996; Loucks-Horsley, Love, Stiles, Mundry & Hewson 2003; Fishman, Marx, Best & Tal, 2003).

Over the years, several professional development programmes have been designed and evaluated according to such frameworks (e.g. Parke & Coble, 1997; Luft 2001; George & Lubben, 2002; Jeanpierre, Oberhauser & Freeman, 2005). In most cases, the intended effects of these programmes were not or only partly accomplished. We have shown elsewhere (Chapter 2), that these studies focus on the effects of their programmes and that little attention is given to the process of professional development, leading to these unsatisfactory results. Furthermore, it is unclear how these frameworks for professional development are elaborated into programmes and how the programme's activities contribute to teacher professional development. According to Hewson (2007), insight into teacher professional development during a programme can provide valuable information about the programme's design. In this study, we aim to acquire insight into the contribution from programme's activities to teacher professional development and contribute to the knowledge base on how to design a professional development programme.

Involvement of teachers in curriculum reforms requires professional development. Traditionally, science curriculum reforms roughly followed a model of research, development and dissemination (Van den Akker, 1998). The research and development were carried out by a small group of curriculum experts, whereas teachers carried out the prescribed curriculum in a way that mostly did not reflect the ideals of the experts (Atkin & Black, 2003). Over the years, science educators and researchers have stressed that for successful and enduring reforms, teachers need to be involved in the design and implementation of new science curricula (cf. Keys & Bryan, 2001). Teacher involvement can vary from adopting curriculum units developed by experts (Bennett & Lubben, 2006) to designing completely new curriculum units (Deketelaere & Kelchtermans, 1996; Eilks, Parchmann, Gräsel & Ralle, 2004). In projects where teachers have been heavily involved in designing new curriculum units, researchers have noted that although teachers enjoy designing, they do not feel confident to design new curricular materials, and they often have difficulties with thinking as designers do (Bencze & Hodson, 1999; Penuel & Gallagher, 2008). Therefore, to successfully involve teachers in a curriculum innovation, professional development should focus on creating teacher confidence for designing new curriculum units.

Science curriculum innovations generally also require changes in pedagogy. Over the years, several context-based courses were developed to motivate students for school chemistry and to induce a 'need to know' among students, which is a need for chemistry knowledge justifying the chemistry concepts to be learned (Gilbert, 2006; Pilot & Bulte, 2006). Teachers generally have a positive attitude towards context-based chemistry education (Van Driel, Bulte & Verloop, 2005). However, they fear that contexts reduce the amount of subject matter, and that they lack the skills and knowledge to teach context-based chemistry properly (Bennet, Gräsel, Parchmann & Waddington, 2005; Coenders, Terlouw & Dijkstra, 2008). To address teacher concerns, and to provide teachers with skills and knowledge to teach context-based chemistry education, professional development could be useful.

Teacher professional development generally focuses on acquiring knowledge and skills. However, change is accomplished when teachers feel sufficiently confident to apply their new knowledge and skills in practice. As such, professional development of teachers is increasingly conceptualised as teacher empowerment (Bell & Gilbert, 1996; Carl, 2009). In this study we used design research to investigate chemistry teacher professional development during an in-service programme. The programme was based on a framework for professional development (Chapter 3). In this paper, we describe the design and evaluation of a professional development programme in which chemistry teachers carried out an educative context-based unit (Davis & Krajcik, 2005), and, based on their teaching experiences, designed an outline of a new context-based unit. In the following section, we will briefly elaborate our framework.

A framework for professional development

To acquire insight into the contribution of the programme activities to teacher professional development, we developed a framework. In this framework, a learning theory, which provided a description of a professional development process, was synthesised with strategies and specific goals for professional development.

As learning theory we used Galperin's theory for the internalisation of actions (Galperin, 1992). It applies a step-by-step strategy to realise the professional development processes that are necessary in mastering an action: building up the motivation, orienting on the action, providing the opportunity to practice with the action, and checking and evaluating the learning process and results. During the mastery of an action, the orienting basis plays an important role. An orienting basis consists of a set of orienting elements by which the learner is guided along in the execution of an action. An orienting basis is initially created by means of an orienting chart, which provides the course of the action and the sequence of its operations in such a way that it serves as a tool of action (Arievitch & Haenen, 2005). Moreover, when the orienting chart is constructed as a meaningful whole, it supports the teacher's motivation for learning. By repeatedly orienting on, practicing with, and reflecting on the action, the orienting basis increasingly expands until mastery of the action is achieved.

The Galperin theory was synthesised with several strategies for professional development: teacher collaboration, reflection on action, educative innovative units and curriculum development (Deketelare & Kelchtermans, 1996; Korthagen & Kessels, 1999; Hawley & Valli, 1999; Loucks-Horsley et al., 2003; Davis & Krajcik, 2005; Carl, 2009). Furthermore, the specific goals of the professional development were incorporated into the framework. These goals consist of cognitive goals, like acquiring knowledge of the nature of the curriculum innovation (context-based chemistry education), and affective goals, like building teacher confidence to apply the innovation in their practice. See Figure 1 for the framework.

The framework consists of two strands, one for teaching (T) and one for designing (D). Each strand consists of three phases, motivation and orientation, application and reflection. During the motivation and orientation phase, teachers create preliminary orienting bases for teaching and designing. An orienting chart is used to create a preliminary orienting basis. Both teaching and designing new curriculum materials are considered to be complex actions (Carl, 2009), for which a preliminary orienting basis and the accompanying orienting chart cannot be complete (Terlouw, 2001). The orienting chart used to create the preliminary orienting bases for teaching and for designing consists of a context-based unit and a general model of such a unit (see the following section).

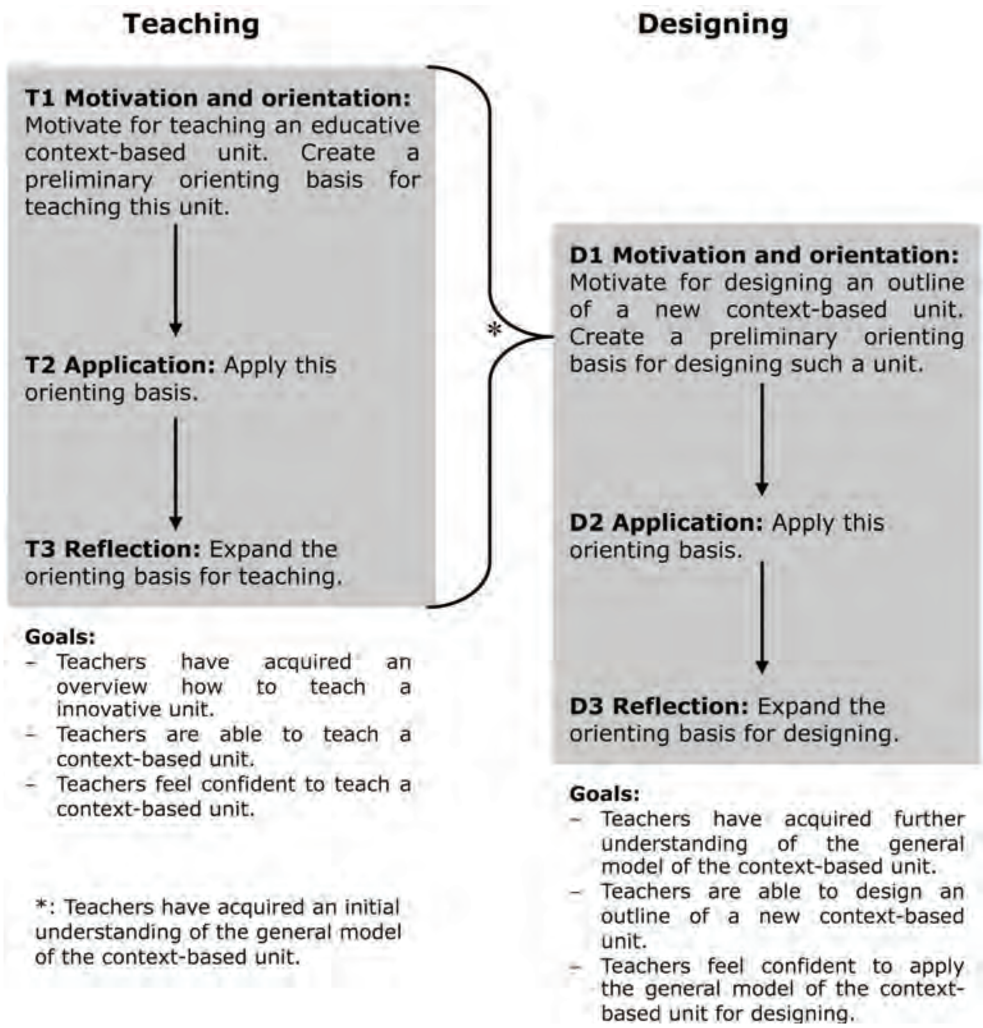

Figure 1: Professional development framework used in this study.

During the motivation and orientation phase of the teaching strand, teachers create a preliminary orienting basis for teaching the context-based unit by becoming acquainted with the context-based unit and its underlying general model. During the application phase, teachers apply their preliminary orienting basis by teaching the context-based unit in their classrooms. During the reflection phase, teachers expand their orienting basis by sharing and discussing their teaching experiences. After the teaching strand, teachers' expanded orienting basis for teaching consists of their ability and confidence to teach a context-based unit, and of their initial understanding of the context-based model. Both strands are connected through the notion that teaching a context-based unit provides teachers with an orienting basis about an educative context-based unit and its underlying model, which can be useful in designing an outline of a new context-based unit. The expanded orienting basis for teaching is considered a suitable preliminary orienting basis for designing an outline of a new context-based unit. During the application phase, teachers apply their preliminary orienting basis, by designing an outline of a new context-based unit. During the reflection phase, teachers expand their orienting basis by sharing and discussing their design experiences. After the designing strand, teachers' expanded orienting basis for designing consists of their ability and confidence to design an outline of a new context-based unit, and of their further understanding of the general context-based model.

Part of the process of internalisation is the frequent repetition of an action. In this framework teachers both teach and design only once. This is in line with the goal of the framework. When teachers have created and expanded their orienting bases for teaching and designing, they have become empowered for designing a new context-based unit. Teacher empowerment consists of the dimensions 'feeling confident' and 'professional growth' (Howe & Stubbs, 1996; Carl, 2009). Feeling confident is operationalised as teachers' involvement in decision-making, autonomy, and self-efficacy (Short & Rinehart, 1992). Professional growth is operationalised as teachers' understanding of the context-based model, and their ability to teach and design a context-based unit (George & Lubben, 2002). When teachers have evolved within these dimensions they have become empowered for designing context-based chemistry education (see the 'Methods' section for further elaboration).

Several frameworks on teacher professional development in the context of educational reform have been published (Bell & Gilbert, 1996; Loucks-Horsley et al., 2003; Fishman et al., 2003). Although, these frameworks emphasise interactions among different aspects of teacher professional development (Hewson, 2007), they do not incorporate a description of a professional development process. Our framework does include such a description, and in this study we will use this framework to develop and evaluate a professional development programme for the empowerment of chemistry teachers.

Orienting chart: The context-based model and unit

As an orienting chart, a context-based unit and its underlying general model were used. The context-based model originated from a group of concerned curriculum experts. In 2000, they proposed to make chemistry more meaningful to the students by embedding chemistry concepts in contexts (Bulte et al., 2000). Their proposal initiated a nation-wide discussion about the chemistry curriculum. A survey carried out with Dutch chemistry teachers showed that a substantial number of these teachers were dissatisfied with the current curriculum, and they wanted more emphasis on societal aspects of chemistry (Van Driel et al., 2005). Furthermore, the expert group advocated involving teachers in the curriculum design process. Similar to the German 'Chemie in Kontext' project in Germany (Parchmann Gräsel, Baer, Demuth & Ralle, 2006), they proposed to establish networks of teachers for the design and evaluation of new context-based units. Interviews with a representative group of chemistry teachers indicated that these teachers are interested in designing new context-based units (Coenders et al., 2008). In 2003, the recommendations of the expert group became the official policy of the Dutch Ministry of Education (Driessen & Meinema, 2003).

According to the expert group, a context-based chemistry curriculum should consist of a series of units. Each unit should be designed from a context, and structured according to a general context-based model (De Vos, Bulte & Pilot, 2002). The model, used in this study, consists of three parts (see Figure 2).

First, students are introduced to a (practical) problem related to the context. This problem evokes students' curiosity and a need for chemistry knowledge to understand and solve the problem (the 'need to know'). The aim of the context-based introduction is to provide an initial context-related justification for studying chemistry concepts. Next, students study these chemistry concepts. Finally, students carry out an inquiry project, in which they apply the chemistry concepts previously studied. The aim of the project is to provide students with a context-related justification in retrospect for studying chemistry concepts. The study of chemistry concepts is carried out simultaneously with an orientation on a context-based inquiry project.

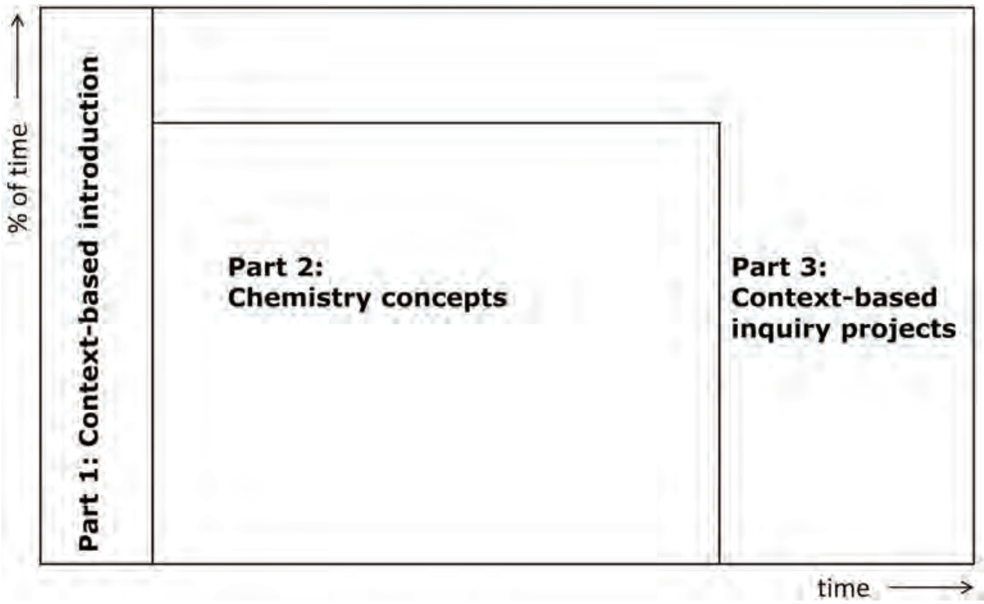

Figure 2: General model of a context-based unit.

The context-based unit used in this study also originated from the expert group. Two teachers, who were members of the expert group, designed a context-based unit according to this general model (Jansen & Kerkstra, 2001). The context was super absorbent materials in disposable diapers. The unit was made for fourth grade, pre-university chemistry classes (15-16 years old students) and consists of the following:

- A context-based introduction, in which students have to conduct an experiment on the absorbing capacity of a disposable diaper. This experiment aims at evoking students' curiosity and evoking a need for explaining why diapers absorb so much liquid ('need to know').
- Chemistry concepts, in which students have to look for explanations for the absorption capacity of disposable diapers by studying a textbook chapter about organic chemistry, viz. hydrocarbons, alcohols, and simple addition and substitution reactions (Pieren, Scheffers-Sap, Scholte, Vroemen, & Davids, 2001). Next, students have to study chemistry concepts from the unit itself, viz. synthesis of polymers and the relation between the water-absorbing properties of polymers and their molecular structure (cross-linked sodium polyacrylate).
- Context-based inquiry projects, in which students investigate, among others, the use of these super absorbent polymers in hair gels and fire-

resistant materials, and apply the chemistry concepts they have studied previously.

This context-based unit is used as an educative unit for participating teachers (Davis & Krajcik, 2005). Its educative nature consists of the use of disposable diapers as a context for studying organic chemistry, the connections between the different parts of the unit and the underlying context-based model. Both the general model and the educative context-based unit will be used as an orienting chart to provide teachers with preliminary orienting bases for both teaching and designing context-based chemistry.

Research question and research strategy

The aims of this study were to investigate how to elaborate the framework into a professional development programme, and to acquire insight into the contribution of the programme activities to the process of professional development. A professional development programme was designed and evaluated. Our research was guided by the following general research question:

To what extent does the elaboration of the professional development framework empower chemistry teachers for context-based designing?

To answer this question, we have used developmental or design research as a research strategy (Lijnse, 1995; Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003; Bulte, Westbroek, De Jong & Pilot, 2006). This strategy constitutes exploring the usefulness and consequences of theoretical ideas by working them out in a professional development process. The professional development process is then optimised in several research cycles, focused on testing, reflecting on and adjusting the designed programme and framework. Testing the designed professional development process takes place in a small-scale case study with a group of teachers as the unit of analysis. The design presented here is informed by theoretical evidence from Chapters 2 and 3. This study reports about the first, explorative, research cycle with the design.

The design is accompanied by a set of expectations on how the programme should function. These expectations describe the (learning) outcomes of each activity, and the actions that teachers are expected to perform. These expectations can be considered as hypotheses, as predictions of the professional development process that is expected to take place. As such, it enables the researchers to precisely observe where the actual professional development trajectory deviates from what was expected. Discrepancies between the expectations and the implemented programme will be used for improving the programme and, pending on the nature of the discrepancies, for improving the underlying framework. To be able to determine whether the elaboration of the framework empowers chemistry teachers for context-based designing, we first describe the activities of the programme and the accompanying expectations. Next, we discuss the evaluation of the design: the methods used and the results obtained.

Design of the programme

The programme is designed starting with the framework (see Figure 1). The phases, goals and strategies are elaborated into specific activities. For each of the activities accompanying expectations are presented. A summary of the programme, including phases and activities is given in Table 1.

Activity T1.1: Exploring the introduction and the inquiry projects of the educative context-based unit

After the teacher-experts presented their context-based unit and its underlying model, the teachers were asked to carry out the introductory student experiment about the absorbing capacity of a disposable diaper. Next, they were asked to develop a research plan for one the inquiry projects. Finally, the introductory experiment and the research plans were discussed. Because context-based teaching is new to the teachers, this activity focused on the new aspects in this unit: the introductory experiment and the inquiry projects. We assumed that the teachers would be sufficiently familiar with the chemistry concepts.

We expected that the teachers would be amazed about the amount of liquid that is absorbed by the diaper and we expected them to indicate that their students would be amazed as well. Furthermore, we expected that the teachers would appreciate the context-based inquiry projects. As such, we considered teachers to be sufficiently motivated for teaching the educative context-based unit.

Activity T1.2: Designing teaching strategies to solve the ´need to know´ problem

The teacher-experts reported that their students did not experience a 'need to know' after they had carried out the introductory experiment.

Their students were not motivated to study a textbook chapter. The teachers were asked to design new teaching strategies through which students would experience a 'need to know' for studying the textbook chapter about organic chemistry. We expected that the teachers would be inspired by the experiences of the teacher-experts and that they would develop teaching strategies to evoke a 'need to know' for studying the textbook chapter. As such, teachers created a preliminary orienting basis for teaching the educative context-based unit.

Table 1: Phases of professional development process and the programme's activities.

Phases		Activity
D1 Provide a general motivation for designing a new context-based unit, and create a preliminary orienting basis for this designing	T1 Provide a general motivation for teaching a context-based unit, and create a preliminary orienting basis for this teaching	T1.1 Exploring the introduction and the inquiry projects of the educative context-based unit.
		T1.2 Designing teaching strategies to solve the ´need to know´ problem.
	T2 Apply this orienting basis	T2 Teaching of the educative context-based unit and the new strategies.
	T3 Expand the orienting basis for teaching	T3 Reflection on teaching.
		D1 This activity is covered by the activities T1 to T3.
D2 Apply this orienting basis		D2 Designing an outline of a new context-based unit.
D3 Expand the orienting basis for designing		D3 Reflection on designing.

Activity T2: Teaching of the educative context-based unit and the new strategies

The teachers were asked to teach the educative context-based unit in their classrooms, and to use their newly developed teaching strategies. We expected that the teachers would use these teaching strategies. Applying the preliminary orienting basis for teaching in a safe environment provided teachers with the possibility to see whether their preliminary orienting basis is suitable or needs to be expanded.

Activity T3: Reflection on teaching

After teaching the educative context-based unit in their classrooms, the teachers were asked to discuss their teaching experiences. Subsequently, they were asked to use these experiences for elaborating the context-based model. First, we expected that the teachers would report that their students were amazed by the properties of disposable diapers. Second, we expected that the teachers would feel confident (that is, they had experienced involvement in decision-making, autonomy and self-efficacy) to teach this context-based unit. Third, we expected that they also would know how to solve the ´need to know´ problem. Finally, we expected that the teachers would use their experiences to elaborate the general context-based model, by discussing which teaching strategies are appropriate for context-based teaching and designing. In this reflective activity, the teachers should expand their orienting basis for context-based teaching. The use of the teaching experiences for elaboration of the context-based model should also contribute to creating a preliminary orienting basis for context-based designing (see Figure 1).

Activity D1: This activity is covered by the activities T1 to T3

We expected that the activities T1 to T3 would provide the teachers with an initial understanding of the underlying general context-based model (See Figure 1, the connection (*) between teaching and designing). More specifically, we expected that the teachers would have acquired knowledge on how to connect the three parts of the model in a new context-based unit. Furthermore, we expected that teachers would be motivated to apply their initial understanding when designing an outline of a new context-based unit. As such, we expected that these activities would motivate teachers to design a new context-based unit, and would provide them with a preliminary orienting basis for designing.

Activity D2: Designing an outline of a new context-based unit

The teachers were asked to design an outline of a new context-based unit. As starting points they used a well-known textbook chapter about the chemical properties and molecular structure of water (Pieren et al. 2001), and the general context-based model. The teachers were asked to design an outline of an introductory experiment which should evoke 'a need to know' for the chemistry concepts in this textbook chapter. Next, the teachers were asked to rearrange the chemistry concepts according to the students' need to know. Finally, the teachers were asked to design an outline of an inquiry project in which students can apply the chemistry concepts. Their outlines should provide students with a justification for studying these concepts. We expected that the teachers would design their outlines according to the context-based model. Because of their experiences with the educative context-based unit, we expected that the teachers would focus on the connection between the context-based introduction, the chemistry concepts and the inquiry projects. This activity should provide the teachers with the opportunity to apply their understanding of the general context-based model, when designing an outline of the new unit. It should provide teachers the possibility to check whether their preliminary orienting basis is suitable, or needs to be expanded.

Activity D3: Reflection on designing

The teachers were asked to report and reflect on their experiences with designing an outline of a context-based unit. We expected that they would report on strategies for designing outlines of new context-based units. As such, the teachers acquired a further understanding of the general context-based model. Furthermore, we expected that they would feel confident to use this model for designing a new context-based unit, that is, they would experience involvement in decision-making, autonomy and self-efficacy. Reflection on the design experiences should expand teachers' orienting basis for context-based designing. As such, teachers should have become empowered for designing context-based chemistry education.

Method

The programme in action

Following the design of the programme, we divided the general research question (To what extent does the elaboration of the framework for professional development empower chemistry teachers for context-based designing?) into ten evaluative sub-questions. Each question is related to an activity of the programme. The code before the question identifies the corresponding activity (see Table 2).

A group of six chemistry teachers, all from different secondary schools, participated voluntarily in the programme. Four teachers (Harry, John, Donald and Norman)[1] had more than twenty-five years of teaching experience each, two teachers (Rick and Louise) had a range of 5 to 10 years of teaching experience. All teachers had a master degree in chemistry. They all had previous experience in other professional

1. All names used in this research study are pseudonyms.

development programmes, and were regular attendees of chemistry teacher conferences. These teachers were willing to use innovative ideas and they supported the context-based curriculum innovation.

The programme covered five three-hour instructional meetings and was accompanied by teaching practice in their respective schools, from October 2001 to April 2002. Table 3 presents the meetings and the activities described in the previous section. All teachers taught the educative context-based unit to their own students (grade 10; ages 15-16) in pre-university schools.

The first and second author designed and planned the meetings. The second author, who is an experienced chemistry teacher educator, chaired all meetings. During the meetings, the first author was present at all times. All authors participated in the evaluation of both individual meetings and the entire programme.

Recruitment efforts included advertisements in the National Dutch Science Teacher Magazine (NVOX), and a direct mailing to about 200 participants from the annual National Chemistry Teachers Conference. Recruitment focused on teachers with leadership qualities who were willing to use context-based chemistry education in their classrooms. During the recruitment procedure, the programme was presented as an introductory course in teaching and designing context-based chemistry education. Teachers were also informed of the research activities which were carried out during the programme. None of the teachers objected to these activities. The programme was free of charge; teachers received compensation for their travel expenses. The programme did not have more teacher application submissions than could be accepted, so no applicants were turned away.

Data collection and analysis

A qualitative methodology was used to identify whether the expectations regarding teachers' professional development processes were met. Data were collected at specific moments that were closely associated with the design of the programme (cf. Baxter & Lederman, 1999). During the meetings, ample field notes were made, and products created by teachers were collected. Between scheduled meetings, several lessons in which the educative context-based unit was taught were observed. When a lesson could not be observed, the teachers filled in a questionnaire in which they evaluated their lesson. Before and after the programme, all teachers were

Table 2: Overview of the programme activities and sub-questions.

Programmes Activities	Sub-questions
T1.1 Exploring the introduction and the inquiry projects of the educative context-based unit.	T1.1 To what extent were the teachers motivated for teaching the educative context-based unit?
T1.2 Designing teaching strategies to solve the ´need to know´ problem.	T1.2 To what extent did the teachers design new teaching strategies to solve the 'need to know' problem?
T2 Teaching of the educative context-based unit and the new strategies.	T2 To what extent did the teachers teach the educative context-based unit and their new strategies?
T3 Reflection on teaching.	T3.1 To what extent did the teachers feel confident to teach such a context-based unit?
	T3.2 To what extent did the teachers use their teaching experiences for elaborating the general context-based model?
D1 This activity is covered by the activities T1 to T3.	D 1.1 To what extent were the teachers motivated for designing a new context-based unit?
	D1.2 To what extent did the teachers acquire an initial understanding of the general context-based model?
D2 Designing an outline of a new context-based unit.	D2 To what extent did the teachers apply the elaborated context-based model for designing an outline of a new context-based unit?
D3 Reflection on designing.	D3.1 To what extent did the teachers feel confident to use a general model for designing?
	3.2 To what extent did the teachers acquire a further understanding of the general context-based model?

Table 3: Meetings and activities.

Meetings	Activities
1*	T1.1 Exploring the introduction and the inquiry projects of the educative context-based unit.
2	T1.2 Designing teaching strategies to solve the ´need to know´ problem.
3 and 4	T3 Reflection on teaching.
1 to 3	D1 This activity is covered by the activities T1 to T3.
4 and 5	D2 Designing an outline of a new context-based unit.
5	D3 Reflection on designing.

*) Teaching of the unit took place in class, between the meetings 1 to 4.

interviewed about their opinions regarding context-based chemistry education and the programme. All audiotapes were transcribed verbatim. Fragments of the critical instances were independently selected by the first and second author to verify whether the professional development process had unfolded as expected. Additional data from teacher products, questionnaires and interviews were used for triangulation when necessary.

As part of answering the sub-questions, the numbers of teachers who fulfilled the expectations related to a particular sub-question was determined. Four categories to indicate the number of teachers were used: all (6 teachers), most (4-5), some (1-3) and none (of the teachers). In some cases, it was not possible to collect data from all teachers due to duties elsewhere or illness. Harry was absent during activity T3, and Rick and Norman were absent during activities D2 and D3 (see Table 1). To determine teacher confidence for teaching and designing a context-based unit (sub-questions T3.1 and D3.1, see Table 2), teacher statements were categorised in terms of their perception of their involvement in a decision-making process, autonomy, and self-efficacy (Short & Rinehart 1992). Thus, for example, when teachers expressed 'to feel confident' for an active role in curriculum innovation, teachers have the perception that they are involved in the decision-making process. In other words, teachers perceive that they have control about certain choices in the curriculum innovation process (autonomy). It is their perception that they can be effective in building programmes for students and to influence the students' learning (self-efficacy).

The result of the analysis was a description of the professional development process in terms of group discussions, and individual teacher statements. Both the first and second author compared and discussed their descriptions until consensus was reached about the findings. Finally, this description about the evaluation of the expectations was discussed with the third and fourth author to accomplish final consensus (investigator triangulation: Janesick, 2000).

Findings

Before answering the main research question (in the conclusions section), we first answer the evaluative sub-questions.

T1.1: To what extent were the teachers motivated for teaching the educative context-based unit?

All teachers were interested in the forthcoming context-based curriculum innovation and in the educative context-based unit. They all indicated hey had heard about this unit, but they had no specific knowledge about its contents. In addition, none of the teachers had previous experiences with context-based chemistry education. Some teachers (Norman, Donald, John) expressed some scepticism towards context-based chemistry education. Their scepticism originated from their previous experiences with other curriculum innovations. After conducting the introductory experiment, all teachers appraised the experiment and they indicated that it would amaze their students. Furthermore, all teachers enjoyed designing a research plan for one of the inquiry projects. These findings indicate that all teachers were motivated to teach the educative context-based unit, and that they all acquired an overview on how to teach this unit.

T1.2: To what extent did the teachers design new teaching strategies to solve the 'need to know' problem?

After the teacher-experts reported their difficulties with creating a 'need to know' among their students, the teachers designed two different teaching strategies to solve the problem. Rick, Louise and John proposed the 'look for unknown words' teaching strategy. In this strategy, students carry out the introductory experiment followed by reading the text from the context-based unit in which the molecular structure of the super absorbent material is described. When the students stumble upon a word they don't understand, they can look it up in their textbooks. Donald, Harry and Norman proposed the 'carefully guiding' teaching strategy. They emphasised the importance of clarifying to students why studying chemistry concepts is necessary. They proposed that the teacher should carefully guide student discussions about the experimental results of the introductory experiment towards the textbook chapter about organic chemistry. All teachers participated in the design of two new teaching strategies, which aimed to solve the 'need to know' problem. The findings from activities T1.1 and T1.2 indicate that the teachers created a preliminary orienting basis for teaching a context-based unit.

T2: To what extent did the teachers teach the educative context-based unit and their new strategies?

All teachers taught the educative context-based unit in their classrooms, and most teachers applied the teaching strategies they had developed in activity T1.2. Rick reported to have applied the teaching strategy ´look for unknown words´:

> Rick: "After my students carried out the introductory experiment I read aloud a short text [from the unit] about how disposable diapers function, including all these chemical terms. I asked 'Is there anybody who can explain me how that diaper works?' Nobody could (..) there are too many concepts in that short text, so, that was not very successful. Then I asked which chapter would you have to study before you could explain how a disposable diaper works? They all pointed to a chapter about polymers (..). But before that, I explained, you have to learn something basic. Yes, they accepted, first, we have to learn something basic, nomenclature of substances, before we, at the very end (..), might understand what diapers are." (meeting 3)

Donald and Norman, who proposed to use a carefully guided discussion about results of the introductory experiment, reported to have used this teaching strategy when teaching the educative context-based unit. Louise and John did not apply this strategy in their practice. They reported to have taught the introductory experiment and the textbook chapter according to the original unit. They explained their teaching behaviour as 'an old pattern of teaching' (John). The teachers' reports were confirmed by lesson observations and written evaluative questionnaires. The data indicate that all teachers were able to teach this unit, however, they had difficulties using the newly developed teaching strategies. All teachers applied their preliminary orienting basis, however, some of the teachers did not apply it completely.

T3.1: To what extent did the teachers feel confident to teach such a context-based unit?

To indicate teacher confidence, exemplary teacher statements and summaries of teacher statements are presented with their assigned category (involvement in decision-making, autonomy, and self-efficacy, see the 'Data collection and analysis' section).

All teachers reported that the introductory experiment about the liquid-absorbing capacity of a diaper evoked a lot of enthusiasm among their students (self-efficacy).

> Donald: "That diaper was full of water (. . .) I could not get it out of the diaper. But there was a very strong boy who tried to squeeze it out. He squeezed too hard, and the filling squirted out of the diaper. However, he did not get the water out. From that moment, that diaper passed from hand to hand, and they were deeply involved." (self-efficacy, meeting 3)

All teachers indicated that they did not solve the ´need to know´ problem in their classrooms. They reported to encounter difficulties in motivating students to study the chemistry concepts about the molecular structure of the super absorbent material. All teachers reported that for many of their students these chemistry concepts were too difficult to understand without extensive teacher support (self-efficacy). With respect to the inquiry projects, all teachers reported that the students were motivated to carry out these projects. They also reported that their students hardly had to apply chemistry concepts in these projects. They concluded that the connection between these concepts and the inquiry projects was not clear (self-efficacy). During the group discussion in meeting 3, all teachers proposed several changes to the unit (autonomy, decision-making, see also the next section). During the post-programme interview, all teachers intended to teach the context-based unit next school year (decision-making). During activity T3, all teachers expressed self-efficacy, autonomy and showed involvement in decision-making, and as such, all teachers felt confident to teach a context-based unit.

T3.2: To what extent did the teachers use their teaching experiences for elaborating the general context-based model?

During the reflective group discussion, all teachers used their teaching experiences to propose adaptations to the educative context-based unit. For example, John proposed to use an analogy for representing polymer structures, before zooming in on alkanes and their nomenclature. Louise, Norman and Donald indicated that they would alter the chemistry concepts, by focussing on the water absorption property of the super absorbent polymers and leave out the synthesis of these polymers and the textbook chapter on the nomenclature of simple hydrocarbons. Although, the teachers did not solve the 'need to know' problem, all teachers used their teaching experiences with the educative context-based unit to propose revisions to this unit and, consequently, elaborated the general context-based model, and acquired an initial understanding of the context-based model. As such, all teachers expanded their orienting basis for teaching.

D1.1: To what extent were the teachers motivated for designing a new context-based unit?

During the pre-programme interviews, all teachers were cautious about designing a new context-based chemistry curriculum, as advocated by the expert group (Bulte et al., 2000). They had experience with adapting pre-developed curriculum materials, but none of them had experience with designing new materials. All teachers indicated that, if they would participate in designing a new chemistry curriculum, they require sufficient time to design a context-based unit, a fee, and support from expert-designers.

Data from activities T1.1 and T3 made clear that teachers were motivated to adapt the educative context-based unit. However, the data collected during activities T1 to T3 does not indicate that teachers were motivated to design an outline of new context-based unit. Nevertheless, in the following design activity (D2) all teachers participated actively.

D1.2: To what extent did the teachers acquire an initial understanding of the general context-based model?

After teaching the context-based unit, all teachers expressed their understanding of the general context-based model. First, they emphasised the importance of a challenging motivating introductory experiment for evoking a ´need to know´ among students. Second, the teachers expressed difficulties in connecting the three parts of the model. To improve the connection between the introductory context and the chemistry concepts they proposed to zoom in from a general chemistry explanation to a more detailed explanation (contrary to the arrangement in similar textbooks chapters). To improve the connection between the chemistry concepts and inquiry projects, they proposed that chemistry concepts should be applied to the inquiry projects. As such, teachers created a preliminary orienting basis for designing a new context-based unit.

D2: To what extent did the teachers apply the elaborated context-based model for designing an outline of a new context-based unit?

All teachers outlined a context-based introduction to the textbook chapter on dipole molecules, polar substances and hydrogen bonds (Pieren et al., 2001). For example, John and Donald began their outline with a question "Why do substances dissolve?' They started with several student experiments on washing and surface tension (e.g. washing hands with different liquids, and soap added to a beaker of water with a floating object) for evoking a 'need to know' for studying the chemistry concepts in the textbook chapter. Next, all teachers sequenced their chemistry concepts similar to the sequence of these concepts in the original textbook chapter. Finally, most teachers designed outlines of context-based inquiry projects. They took several different laboratory experiments from the textbook chapter, and labelled them as inquiry projects.

Teachers' outlines for a new context-based unit differed from their adaptations to the educative context-based unit as proposed in activity T3. These differences can be caused by the difference in context and chemistry concepts between the educative unit and teachers' outlines (e.g. diapers and polymers vs. cleaning and dipole molecules). However, in designing their outlines, teachers did not pay explicit attention to connections between the context-based introduction, the chemistry concepts and the inquiry projects. They did not consider the nature of students' 'need to know' and its consequences for the chemistry concepts. Although, the inquiry projects did require the application of chemistry concepts, these projects were 'cook book' laboratory experiments, with no possibility for inquiry. In sum, none of the teachers applied the elaborated context-based model in designing an outline of a new context-based unit, and they did not apply their preliminary orienting base for designing.

D3.1: To what extent did the teachers feel confident to use a general model for designing?

To indicate teacher confidence, exemplary teacher statements and summaries of teacher statements are presented with their assigned category (involvement in decision-making, autonomy, and self-efficacy, see the 'Data collection and analysis' section).

All teachers encountered difficulties during the design of an outline of a new context-based unit. For example, teachers had difficulties in assessing whether a context-based introduction would motivate students for studying the chemistry concepts.

> Louise: "It is difficult to design a proper introduction (. . .) it is difficult to assess. Something that students consider as very simple can be offered it in such a way that they start to consider it as interesting. I had never expected that. For instance, regarding that diaper, they were more enthusiastic about it than I had estimated. Realising something like that for a new topic, yes, that is hard for me." (self-efficacy, meeting 5)

All teachers appreciated the use of the context-based model in the design task (self-efficacy).

> Donald: "I was confronted with how to use such a model [concept-context approach]. Especially, the fifth meeting was wonderful. We had to look forwards (...), and thereafter, you integrate the knowledge you have acquired, you apply it." (self-efficacy, post-programme interview)

Some teachers explicitly mentioned that they wanted to use motivating introductory experiments when starting with a new textbook chapter (decision-making, autonomy).

> Louise: "I want to try to motivate students for studying theory by starting from daily-life situations, (...) for example, the chapter about methods for separation of chemicals, can be started with an experiment which shows students that you can make cola clear, without losing its taste, instead of the usual textbook approach." (decision-making, autonomy, meeting 5)

D3.2: To what extent did the teachers acquire a further understanding of the general context-based model?

Teachers did not apply the context-based model while designing the outline. Therefore, results about their further understanding of the model are scarce. However, all teachers indicate that their preliminary orienting basis for designing is not suitable for designing new context-based units, and it needs to be expanded. Harry, Louise, John and Donald expressed a fixed view of the arrangement of the chemistry concepts in current textbooks.

> Louise: "For me, all these meetings clarify that; anyhow, I am rather fixed regarding the way to teach some topics. You are following the textbook rather automatically, and, yes, over the years, you become less critical of how it is structured." (post-programme interview)

Furthermore, these teachers reported difficulties in teaching according to a general context-based model. This model implies a proper connection between chemistry concepts as presented in current textbooks, a motivating introduction and context-based inquiry projects.

> Donald: "If I would teach the unit again next year (...) I don't think I would use the textbook chapter [about organic nomenclature] again. I would teach it as a separate project, not connected to the textbook theory." (post-programme interview)

In answering question D3.1, all teachers expressed self-efficacy and most of them showed autonomy and involvement in decision-making. This indicates that most teachers felt confident to use a general model of a context-based unit for designing. In answering question D3.2, based on the limited amount of data, design activity D2 did not provide teachers with further understanding of the context-based model.

Conclusions

The research question in this study was 'To what extent does the elaboration of the professional development framework empower chemistry teachers for context-based designing?' To answer this question, a professional development programme based on a specific framework was implemented. The programme was evaluated by comparing the actual process of professional development with the process of professional development intended by its developers (the expectations).

The answers to the sub-questions (see Table 2) show that our expectations were largely accomplished. All teachers were motivated to teach the educative context-based unit, and they all adapted the educative context-based unit by designing new teaching strategies, which aimed to solve the 'need to know' problem. Subsequently, all teachers taught the educative context-based unit, and most teachers applied their pre-developed teaching strategies. Furthermore, all teachers felt confident to teach a context-based unit, proposed revisions to this unit and, consequently, elaborated the general context-based model.

During the design activities, however, the actual professional development process deviated form our expectations. First, the teaching strategies designed to solve the 'need to know' problem (activity T1.2) were rather superficial, and, after applying these strategies, it became clear to the teachers that these strategies did not solve the 'need to know' problem. Second, all teachers encountered difficulties in designing an outline of a new context-based unit (activity D2), like designing a context-based introduction and changing the sequence of chemistry concepts in a textbook chapter. During the design, none of the teachers applied the elaborated context-based model. Third, all teachers created a preliminary orienting basis for teaching the educative context-based unit. All teachers applied their preliminary orienting basis, however, some of the teachers did not apply it completely. As such, all teachers expanded their orienting basis for teaching and created a preliminary orienting basis for designing a context-based unit. But, during design of an outline of a new context-based unit, the teachers did not apply their preliminary orienting basis. However, they did notice that their preliminary orienting basis for designing was not suitable for designing new context-based units, and needed to be expanded.

With respect to the goals of the framework, all teachers felt confident to teach a context-based unit. In addition, all teachers grew professionally in terms of the ability to teach a context-based unit, and their understanding of the context-based model. Furthermore, most teachers felt confident to design a new context-based unit, and all teachers were able to design an outline of a new context-based unit. However, their professional growth was limited to the ability to design an outline. The design activity did not provide teachers with sufficient further understanding about the context-based model. As such, teachers were only partly empowered for designing new context-based units. In conclusion, the framework was not sufficiently elaborated to completely empower chemistry teachers for context-based designing.

Discussion and implications

The present study has shown that it is possible and fruitful to develop and evaluate a professional development programme based on a framework consisting of a model of teacher professional development. Focus on the process provides an improved insight into the quality of the programme's design and pinpoints successful and less successful activities (Hewson, 2007). For example, teaching an educative context-based unit is a fruitful strategy to learn about the nature of a curriculum innovation. As an orienting chart, it contributes in creating an orienting basis for teaching such context-based units. However, it did not provide teachers with a suitable preliminary orienting basis for designing. Furthermore, the framework was not sufficiently elaborated to completely empower chemistry teachers for context-based designing. Therefore, the programme needs to be revised and the framework needs to be reconsidered.

- First, the educative unit needs to embed teaching strategies, which solve the 'need to know' problem. As such, teachers will become acquainted with solutions for the 'need to know' problem, and be able to apply these solutions while designing a new context-based unit.
- Second, in designing an outline of a new context-based unit, teachers should have access to more resources other than a well-known chapter from a textbook. Furthermore, the design of an outline should focus on designing connections between the context-based introduction, chemistry concepts and inquiry projects, instead of designing new contexts and inquiry projects. With an example of a successful solution for the 'need to know' problem and with an improved design activity, teachers are likely to create and apply their preliminary orienting basis for designing, and become empowered for designing new context-based units.
- Third, the results of this study should be incorporated into the framework. For example, in order to increase the applicability of the framework for designing professional development programmes, general descriptions of suitable activities will be added to each phase of the professional development process.

However, the findings, conclusions and suggested improvements are subject to several limitations. Firstly, it should be noticed that the authors acted as designers, implementors and evaluators of the professional development programme. Although there is concern about developers being suitable evaluators (Jeanpierre et al., 2005), conversations about the data analysis occurred in the context of formative evaluation, because the authors wanted to learn as much as they could to improve the programme. Secondly, the teacher educator being part of the project staff raises questions about the transferability of the programme. The role of the teacher educator will be evaluated when a successful programme is designed and enacted. Thirdly, we relied on interviews and open-ended questionnaires, that is, qualitative data sources in which researcher bias and social desirability effects can play a role (Creswell, 2006). We only can assume that teachers were sincere in their remarks during programme meetings and answers to interview questions. Fourthly, the results are based on six chemistry teachers only. These teachers are not likely representative for the majority of the chemistry teachers in the Netherlands (Van Driel et al., 2005). Whether the results can be generalised to other teachers in other science domains is subject for further study. The fifth limitation relates to the stage of the curriculum innovation. This study was carried out during the initial stage of a context-based curriculum innovation. Although there was a lot of public debate about the chemistry curriculum, the innovation was not yet official governmental policy. Whether the professional development programme is applicable in other stages of the curriculum reform needs to be investigated further (Starkey et al., 2009).

In conclusion, the framework might indeed serve as a starting point for designing a professional development programme, which empowers chemistry teachers to design context-based chemistry education. A next step in our research will be to focus on solving the above-mentioned problems in the programme design and carry out the revised programme under different circumstances, with different teachers and a new teacher educator. In doing so, we aim to make the programme and the framework applicable more widely and more robustly (Borko, 2004).

Many research studies have been conducted on teacher professional development programmes during teacher-based curriculum innovations. In general these studies pay little attention to the professional development process during these programmes. They mostly focus on the effects of these programmes. In the present study an effort has been made to contribute to the knowledge about the processes of teacher professional development during this kind of innovation. Insight in the professional development process contributes to an improved understanding on how to design professional development programmes. In subsequent studies we aim to further contribute to the development and elaboration of knowledge for designing professional development programmes for teacher-based curriculum innovations.

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	Chapter 1 **Introduction and overview** General research question: What constitutes a professional development framework for designing and evaluating a programme to empower teachers for context-based chemistry education?
	Chapter 2 **Towards a professional development framework: Goals, strategies and rationale** In this chapter the goals and strategies are presented for a professional development framework for designing and evaluating a programme to empower chemistry teachers for context-based education.
First Research Cycle	**Chapter 3** **Towards a professional development framework: Learning theory and synthesis** This chapter describes the synthesis of a learning theory, goals and strategies in a framework for professional development to empower chemistry teachers for context-based education.
	Chapter 4 **Evaluation of a professional development framework to empower chemistry teachers for context-based education** This chapter describes an elaboration of the framework into a programme for professional development. The enactment and evaluation of the programme with a group of experienced chemistry teachers are presented.
Second Research Cycle	**Chapter 5** **Evaluating a refined professional development framework to empower chemistry teachers for context-based education** This chapter considers the refined framework and its elaboration into a new programme. The enactment and evaluation of the new programme with a new group of experienced chemistry teachers are described.
	Chapter 6 **Conclusions and reflection** This chapter summarises all major findings and conclusions of the study. It reflects on the both the findings and the research method.

Chapter 5

Evaluating a refined professional development framework to empower chemistry teachers for context-based education

In this chapter, the design, implementation and evaluation of a second version of the programme, based on a refined professional development framework (see Chapter 4), is described. The programme is carried out with a new group of seven chemistry teachers. Evaluation of the programme focuses on revisions made to the programme, and whether teachers indeed felt empowered for context-based chemistry education. The findings indicate that teachers became empowered to design context-based chemistry education, provided they had sufficient time and resources. The findings also show the influence of the curriculum leader and the influence of teachers' professional knowledge on the professional development process. The results are used to reflect on the professional development framework. Implications for the programme and the framework are discussed.

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Chapter 5

Evaluating a refined professional development framework to empower chemistry teachers to design context-based education

Abstract

Even experienced chemistry teachers require professional development when they are encouraged to become actively engaged in the design of new context-based education. This study briefly describes the development of a framework consisting of goals, learning phases, strategies and instructional functions, and how the framework was translated into a professional development programme intended to empower teachers to design context-based chemistry education. The programme consists of teaching a pre-developed context-based unit, followed by teachers designing an outline of a new context-based unit. The study investigates the process of teacher empowerment during the implementation of the programme. Data were obtained from meetings, classroom discussions and observations. The findings indicated that teachers became empowered to design new context-based units provided they had sufficient time and resources. The contribution of the framework to teacher empowerment is discussed.

Introduction

Many countries have experienced a wave of chemistry curriculum innovation aimed at meaningful student learning. One way of introducing meaningful learning is the use of contexts. The introduction of contexts in chemistry teaching induces for the students a need for exploring related chemistry knowledge (Pilot & Bulte, 2006). Moreover, teachers are encouraged to get more involved in the innovations; as part of networks supervised by curriculum leaders, they design and evaluate new context-based units (Parchmann Gräsel, Baer, Demuth, & Ralle, 2006; Bulte & Seller, 2011). This places new demands on the professional development of chemistry teachers.

While teachers regularly create lessons for their classes, they find larger and more systematic curriculum development challenging. Teachers generally do not regard themselves as designers of innovative curriculum materials. Many teachers do not feel confident in designing materials and they find it difficult to think as designers (George & Lubben, 2002; Penuel & Gallagher, 2009). Therefore, in order to involve teachers successfully in these materials design networks, a programme is required in which empowers chemistry teachers for their new role in context-based innovations.

Many studies have focused on the outcomes and impact of professional development (cf. Supovitz & Turner, 2000; Jeanpierre, Oberhauser, & Freeman, 2005). More recently, research into teacher professional development has examined the process of professional development and not only its outcomes (cf. Hanley, Maringe, & Ratcliffe, 2008; Van der Valk & De Jong, 2009). According to Hewson (2007), insights into the process of professional development can provide valuable information about the design of the professional development programme.

In investigating the process of teacher empowerment we developed a professional development framework (Chapters 2 and 3). This framework acts as a blueprint for a professional development programme and as a predictor for the process that is expected to take place. The framework consisted of goals, strategies and phases. In Chapter 4, we reported on an explorative research cycle (see the Methods section below for further explanation) in which the framework was transformed into a programme, which was carried out and evaluated. Results from this study indicated that teachers were only partially empowered to design context-based units. The following three problems were identified:

a. (a)the phases and strategies in the framework did not provide sufficient guidance in designing the programme's activities;
b. (b)in the pre-developed context-based unit, the 'need to know' principle was not properly designed; and
c. during the design of an outline of a context-based unit, teachers had difficulties with designing a suitable context-based introduction.

In this paper, we report on the second research cycle with an improved framework and programme. To address the three problems, we made the following changes to the framework and programme: (a) we incorporated instructional functions into the framework, (b) we incorporated 'students' questions' and 'concept-related hypotheses' into the pre-developed context-based unit and (c) we restructured the design of an outline of a context-based unit. The programme does not aim to transform teachers into full-fledged designers, but to empower teachers to design context-based units in teacher networks. The evaluation is focused on changes made to both the framework and the programme. We will discuss the framework and the programme, report on the observed outcomes in practice, and evaluate the implementation of the programme and the framework. The aim of this paper is to contribute to the knowledge base on how to design programmes to empower teachers for designing context-based learning units.

Theoretical framework

In the following section, the professional development framework is presented. Next, the design of the programme and the research questions are described.

Professional development framework

The professional development framework which is used in this study to develop the programme and to investigate the process of teacher empowerment is presented in Figure 1.

As shown in Figure 1, the framework consists of goals, strategies, phases, and instructional functions.

Teaching | **Designing**

0 Create conditions for empowerment

a. Motivate teachers.
b. Clarify learning goals.
c. Connect to teachers' views on context-based chemistry education.

Teaching

T1 Orientation: Create a preliminary orienting basis for teaching a context-based unit.

d. Let teachers discover differences and similarities among their views on context-based chemistry education and the context-based unit.
e. Show how to teach the context-based unit, give examples and present conditions for use.

T2 Application: Apply this orienting basis.

f. Provide the opportunity to apply the knowledge and skills in practice.

T3 Reflection: Expand the orienting basis for teaching.

g. Give teachers the opportunity to reflect on their teaching and learning experiences.
h. Examine the learning results by creating the opportunity for teachers to produce a product.
i. Evaluate the learning results.

Goals:

- Professional growth: The teachers have acquired an overview of how to teach a context-based unit and the teachers are able to teach a context-based unit.
- Personal growth: The teachers feel confident to teach a context-based unit (involvement in decision-making, autonomy and self-efficacy in teaching).

*: Teachers have acquired an initial understanding of the general model of the context-based unit.

Designing

D1 Orientation: Create a preliminary orienting basis for designing a new context-based unit.

j. Let teachers discover differences and similarities among their views on designing context-based chemistry education and design of the context-based unit.
k. Show how to design context-based units, give examples and present conditions for use.

D2 Application: Apply this orienting basis.

l. Provide the opportunity to apply the knowledge and skills in practice.

D3 Reflection: Expand the orienting basis for designing.

m. Give teachers the opportunity to reflect on their design and learning experiences.
n. Examine the learning results by creating the opportunity for teachers to produce a product.
o. Evaluate the learning results.

Goals:

- Professional growth: The teachers have acquired a deeper understanding of the general model of a context-based unit and the teachers are able to design an outline of a new context-based unit.
- Personal growth: The teachers feel confident to use the general model of a context-based unit for designing (involvement in decision-making, autonomy and self-efficacy in designing).

Figure 1: The refined professional development framework used in this study.

Teacher empowerment generally consists of professional and personal growth (Short & Rinehart, 1992; George & Lubben, 2002). To accomplish both professional and personal growth of teachers, the following strategies were incorporated into the framework: 'teaching an exemplary, pre-developed context-based unit', 'designing an outline of a new context-based unit' and 'interacting with colleagues and curriculum leaders' (Davis & Krajcik, 2005; Parchmann et al., 2006; Deketelaere & Kelchtermans, 1996). Both the teaching and designing strands consist of three phases, which originate from Galperin's theory for the internalisation of actions (Arievitch & Haenen, 2005). In each phase, the orienting basis plays an important role. An orienting basis consists of a set of orienting elements that guide the learner through the action. In the teaching strategy, these orienting elements are the general context-based model and the exemplary, pre-developed context-based unit (see the 'Setting of the study' section below for further explanation), and in the designing strategy, these elements are teachers' experiences with both the model and the unit.

The outcomes of the explorative research cycle suggested that the framework required expansion (Chapter 4), in particular the incorporation of instructional functions. Instructional functions are general operations or measures that have to be implemented in order to complete the stages of a learning process, and they form a transition between the phases and the activities of the programme (Mettes, Pilot & Roossink, 1981). Instructional functions provide guidelines to design and plan the programme's activities, and they make these activities more effective and transparent (Terlouw, 2001). The refined framework in Figure 1 reflects the links between the phases including the instructional functions, and the goals for teacher empowerment and the professional development strategies.

Design of the programme

The framework is elaborated into a programme with the following activities and materials.

0. Create conditions for empowerment: Teachers are motivated to participate in the programme by their desire to teach a pre-developed context-based unit and to learn collaboratively about the new context-based curriculum given their new role in this curriculum (function a). The participants are sent an extensive description of the programme along with the materials of the pre-developed context-based unit, thus familiarising them with the learning goals of the programme (function b). Participating teachers are asked to fill a questionnaire about their views on contexts in chemistry education before the start of the programme (function c).

T1 Orientation: A group of teachers, supervised by a curriculum leader (CL), are prepared for teaching the pre-developed context-based unit. Teachers carry out parts of the unit (see Table 2) as if they were students and explore strategies for teaching these parts (function e). The CL also asks the teachers to report on their initial views of context-based chemistry education, and to discuss similarities and differences between their views, the features of the context-based unit and the underlying model (function d).

T2 Application: The teachers use the context-based unit in their classrooms and apply the teaching strategies that were explored in the orientation phase (function f).

T3 Reflection: The CL encourages collaborative reflection on the teaching experiences (Function g). He asks the teachers to use their experiences to elaborate strategies for teaching similar context-based units (function h) and to evaluate their usefulness in practice (function i).

D1 Orientation: This phase is covered by the activities T1, T2, and T3 (functions j and k). These activities should provide the teachers with an initial understanding of the context-based curriculum model (see Figure 1), and how to apply this model while designing an outline of a new context-based unit.

D2 Application: During the explorative research cycle (Chapter 4) it became clear that teachers had difficulties in designing an outline of a context-based unit. Starting from specific chemistry concepts, teachers were not able to generate a suitable 'need to know' context for students. To address this problem, the researchers concluded that this activity needed to be adapted. The new activity starts with a pre-selected set of context-based introductions, rather than with specific chemistry concepts. Firstly, the teachers select a suitable context-based introduction from the given set of possible introductions. Secondly, they select and structure chemistry concepts that students need to study in order to satisfy their 'need to know'. Finally, the teachers develop an appropriate context-based inquiry project (function l). These adaptations change the meaning of the activity 'designing an outline of a context-based unit' from creatively developing a 'need to know' context to selecting and structuring a 'need to know' context and its accompanying concepts.

D3 Reflection: The teachers complete a questionnaire about their perceptions of the design of an outline of a new unit. Their answers are then discussed (functions m and n). Subsequently, teachers elaborate strategies for designing similar context-based units and evaluate their usefulness in practice (function o).

Research questions

The overarching research question that guided this study was:

> *To what extent does the refined professional development framework empower chemistry teachers for context-based education?*

This question is operationalised into ten sub-questions evaluating to what extent the programme proceeds as expected and results in the intended teacher empowerment. Each question is related to an activity within the programme. The code before the question identifies the corresponding activity (Table 1).

Table 1: Overview of programme activities and sub-questions.

Activity	Sub-questions
0	To what extent did the recruitment procedure create the conditions for empowerment?
T1	1. To what extent did the teachers explore strategies for teaching the context-based unit?
	2. To what extent did the teachers become aware of the differences and similarities between their own views on contexts and the context-based model?
T2	To what extent did the teachers apply these teaching strategies?
T3	1. To what extent did the teachers elaborate strategies for teaching context-based units?
	2. To what extent did the teachers feel confident in teaching such a context-based unit?
D1	To what extent did the teachers use their teaching experience to explore strategies for designing context-based units?
D2	To what extent did the teachers apply these strategies in designing an outline of a new context-based unit?
D3	1. To what extent did the teachers elaborate strategies for designing context-based units?
	2. To what extent did the teachers feel confident in designing a new context-based unit?

Setting of the study

In 2000, a group of concerned curriculum experts proposed making Dutch upper secondary chemistry education more meaningful for students by embedding chemistry concepts in context. To involve teachers in the innovation, the expert group advocated establishing networks of teachers working on the design and evaluation of new context-based units (Bulte et al., 2000). Their proposal initiated a nationwide discussion about the chemistry curriculum. A survey of Dutch chemistry teachers showed that a substantial number of these teachers were dissatisfied with the existing curriculum, and they wanted a stronger emphasis on the societal aspects of chemistry (Van Driel, Bulte & Verloop, 2005). In June 2003, these recommendations became the official policy of the Dutch Ministry of Education for a new context-based chemistry curriculum to be implemented in 2012 (Driessen & Meinema, 2003).

According to the expert group, a context-based chemistry curriculum should consist of a series of units. Each unit should be designed from a context, and structured in accordance with a generic context-based model. This model consists of three parts, a context-based introduction, chemistry concepts and context-based inquiry projects (De Vos, Bulte & Pilot, 2002). Based on this model, the expert group developed a context-based unit as an example of a future context-based chemistry curriculum (Jansen & Kerkstra, 2001). The context of this unit is super-absorbent materials used in disposable diapers. The unit is made for tenth grade, pre-university chemistry classes (15-16 year old students).

The explorative research cycle (Chapter 4) suggested that this context-based exemplary unit did not satisfy students' 'need to know'. It was apparent that the different parts of the unit were not sufficiently connected. To improve the link between the context-based introduction and the chemistry concepts, students' questions about super-absorbent materials were elicited during the introduction. In addition, the study reversed the traditional sequence of chemistry concepts (which started with small simple organic compounds and proceeded via synthesis of polymers towards the structure of super absorbents) in order to align them with the expected 'need to know' in students' questions. Furthermore, 'concept-related research hypotheses' were included in the context-based inquiry projects to strengthen the link with the chemistry concepts (Bulte & Genseberger, 2003). Both the model an the revised context-based unit are presented in Table 2.

Table 2: The context-based model and unit.

Part	Model	Unit
1. Context-based introduction	Students are introduced to a (practical) problem related to a context. This problem aims at evoking students' curiosity and a need for chemistry knowledge to understand and solve the problem ('need to know'). The aim of the context-based introduction is to provide the students with a context-related justification for studying chemistry concepts.	The problem is to investigate which substance is responsible for the large absorbing capacity of disposable diapers. The 'need to know' consists of explaining why super absorbents absorb so much water. To make students' 'need to know' more concrete, they are asked to write down questions, which focus on what they would like to know about the super absorbent. Teacher and students discuss and select suitable questions. These questions will be answered while studying the forthcoming chemistry concepts.
2. Chemistry concepts	Students study the chemistry concepts.	A molecular explanation of the absorption capacity of the super absorbent (cross-linked sodium polyacrylate) is presented. It starts with the representation of polymer chains as spaghetti-like structures and slowly zooms into the monomers and their functional groups. During the teaching of the chemistry concepts, teachers and students collaboratively answer previously generated student questions.
3. Context-based inquiry project	Students carry out an inquiry project, in which they apply the chemistry concepts previously studied. The aim is to provide the students with a context-related justification after they studied the chemistry concepts.	Students investigate variances in the absorption of several different substances. As part of their research plan, they formulate concept-related research hypotheses, in which they predict the absorption capacity of these various substances and explain differences by variances in the molecular structures of substances.

Method

Research strategy

The present study used developmental or design research (Lijnse, 1995; Cobb, Confrey, diSessa, Lehrer & Schauble, 2003; Bulte, Westbroek, De Jong & Pilot, 2006), in order to answer the overarching research question and to study the empowerment process in detail. Using this design-based research strategy, a framework (Figure 1) is designed, and then optimised in several research cycles that focus on testing, reflecting on and adjusting the programme and the framework. This framework is used to describe and evaluate the process of empowerment that is expected to take place. To make this possible, the design of the programme is accompanied by a set of sub-questions (Table 1) used to evaluate to what extent the programme proceeded as planned and resulted in the intended teacher empowerment. Discrepancies between the designed programme and the implemented programme are considered as insights into ways of improving the programme and framework. Testing the designed empowerment process took place in a small-scale case study, with a group of teachers as the unit of analysis. This study reports on the second research cycle of this design-based research strategy.

The programme in action

Seven chemistry teachers, all from different secondary schools, participated voluntarily in the programme with the support of their school administrators. Three teachers (Peter, James and Roger) had more than 20 years of teaching experience each; the other four teachers (Michael, Clive, Jeremy and Sean)[1] had between 3 and 10 years of teaching experience. Six teachers had a master's degree in chemistry and one teacher (Michael) was studying for his master's degree. All of the teachers had participated in other professional development programmes, and regularly attended conferences for chemistry teachers. Their schools received financial compensation for their teacher's participation. The programme covered five 3-hour meetings and classroom practice in their respective schools between October 2003 and February 2004. All teachers taught the context-based unit (see Table 2) with their students in Grade 10 (ages 15 and 16) in a pre-university stream.

The project staff included the first author, the CL (an experienced chemistry teacher educator) and the second author. The project staff

1. All names used in this research study are pseudonyms.

designed all meetings. Evaluators included the project staff and the third and fourth author. The CL led all meetings, with the first author present. Formative evaluation occurred throughout the programme. During the implementation of the programme, the project staff reflected on individual meetings and fine-tuned the design of subsequent meetings.

Data collection and analysis

A qualitative methodology was used to provide answers to the sub-questions (Table 2). All meetings were audio recorded and the first author made detailed field notes. All products created by teachers during the meetings were collected. In between scheduled meetings, the teachers videotaped those lessons in which they used their students' questions, and they recorded tutorial conversations with their students about their content-related hypotheses. The teachers also filled in questionnaires evaluating these lessons and conversations. Prior to the programme, teachers were interviewed about teaching and designing context-based chemistry education. They also completed a questionnaire eliciting their views on context-based chemistry education. After the programme, teachers were interviewed about the programme, its outcomes and about teaching and designing context-based chemistry units. Audio recordings were made of all interviews. All audio and video recordings were transcribed verbatim.

The first and second author independently analysed the empirical data. To answer the sub-questions, fragments (statements from individual teacher interviews and group discussions) were selected from the transcripts. If both researchers selected the same fragment, then it was used for further analysis. If not, it was discussed until they reached a consensus about the usefulness of the fragment. An intercoder agreement of 80% was achieved indicating the lower limit for a substantial level of agreement (Miles & Huberman, 1994). Furthermore, four categories were used to indicate the number of teachers expressing selected views: *all* (7 teachers), *most* (4 to 6 teachers), *some* (1 to 3 teachers) and *none* (0 teachers).

To determine teacher confidence in teaching and designing a context-based unit (sub-questions T3.1 and D3.1, see Table 2), teacher statements were categorised in terms of their confidence ('involvement in decision-making', 'autonomy' and 'self-efficacy'; see Figure 1). For instance, when teachers said that they feel they have an active role in curriculum innovation, this was categorised as a perception of considerable involvement in the decision-making process. When teachers said that they feel they have a large degree of control over the curriculum innovation process, this was categorised as showing autonomy. When they indicated that in their perception they could be effective in building programmes for students and influence students' learning, this was categorised as self-efficacy.

The analysis resulted in a description of the empowerment process based on data from group discussions and individual teacher statements. Both the first and second author compared and discussed their descriptions until consensus was reached. Finally, these descriptions were discussed with the third and fourth author till final consensus was reached (investigator triangulation: Janesick, 2000).

Findings

The findings are presented according to the evaluative sub-questions each answered in a qualitative way, i.e. for the extent to which each programme activity proceeded as planned, and contributed to the intended teacher empowerment.

0. To what extent did the recruitment procedure create the conditions for empowerment?
The pre-programme questionnaires showed that the teachers generally viewed contexts as a practical introduction to study chemistry concepts (see Table 3).

Table 3: Teachers' examples of context-based chemistry education.

Teacher	**Context and chemistry concepts**
Dick	Minerals to introduce the chemical structure of salts.
Jeremy	Contents of a Bacardi Breezer bottle to introduce separation methods.
Sean	Crude oil to introduce hydrocarbons.
Peter	Explosions to introduce the theory of combustion.
James	Waste disposal to introduce deposition reactions with ions.
Roger	Water purification to introduce deposition reactions with ions.
Clive	Synthesis of nylon to introduce polymers.

During the pre-programme interviews, all teachers indicated that they were interested in the proposed curriculum innovation. They were also eager to implement the context-based unit in their own classrooms. As Jeremy stated:

> I really would like to try-out the context-based unit about super absorbents, I have heard so much about it.

During the first meeting, all teachers indicated that the purpose and nature of the design activities were not clear to them. For example, Peter stated:

> I thought that we were going to explore and try-out the context-based unit about super absorbents. I didn't know what the programme description meant by 'designing a new context-based unit'.

Their intentions focused on trying out the unit, not so much on (re)designing a context-based unit. After the CL discussed the goals of the programme, the teachers indicated that they had obtained a clearer perspective on the goals of the programme and planned activities. They all agreed with the proposed goals, and continued to participate in the programme.

The recruitment procedure created, to a certain extent, the conditions for empowerment. It motivated teachers to proceed with the programme (function a), and after discussion, it clarified the programme's goals (function b). Whether the recruitment procedure connected with teachers' views of context-based chemistry education (function c) could not be established from the data of the recruitment procedure. We will address this function in answering question T1.2.

T1.1: To what extent did the teachers explore strategies for teaching the context-based unit?

During the first meeting, teachers carried out the diaper experiment, and they anticipated the types of questions that their students were likely to ask. All teachers recognised that the experiment would generate many questions among students. They also acknowledged that these questions would be geared towards further inquiry of the super absorbents and not towards explaining its properties by its molecular structure. As intended, the teachers concluded that the selection and reformulation of student questions would encourage students to answer their questions using the appropriate chemistry concepts. They reformulated the anticipated student questions and discussed the results. For example, they reformulated 'What happens when you swallow a mouthful of super absorbent?' into 'What will happen with the super-absorbent molecules if water is being absorbed?'. Finally, all teachers agreed that showing the questions in a central place in the classroom while teaching the chemistry concepts is an effective strategy.

During the discussion, led by the CL, the teachers realised that they should be careful not to introduce new chemistry concepts in the reformulated questions because students might no longer recognise the original question. They concluded that student questions should be formulated in order to direct student thinking to the molecular structure of the super absorbent (see transcript below).

CL: The reformulated question, 'What will happen with the super-absorbent molecules if the water is being absorbed?', consists of a new feature, which has not been mentioned before, that you try to incorporate molecules into the question. Has anyone also tried to incorporate molecules into their reformulated questions?

Peter: Well, not directly. Our reformulated question is, 'How do you explain that the super absorber absorbs so much water?'. Our aim is to explain this property with the molecular structure of the super absorbent.

Clive: Our reformulated question is 'Why is it possible to squeeze water from a sponge and not from a diaper?

Sean: It is unlikely that students would talk about molecules in their questions.

CL: You would not use the word 'molecules' in your reformulated questions?

Sean: No, absolutely not. When you introduce such a concept, it is likely that students would not recognise their original question anymore.

CL: I understand. What do you [refers to the other teachers] think about introducing chemistry concepts in the reformulated questions?

James: I agree with Sean, I think it would be better to avoid chemistry concepts in the reformulated questions. [Other teachers agree as well]

CL: So you would be looking for a way to reformulate the question, which focuses student thinking towards the molecular structure of super absorbents, without introducing chemistry concepts

> into the question, in such a way that students would recognise their own question. We have seen several examples of that kind of reformulated questions which give you an opportunity to focus student thinking in the desired direction.

This transcript also demonstrates the different roles of the CL. He focused the discussion (on an important aspect of this reformulated question) without presenting his opinion on the subject, posed clarifying questions, involved other teachers in the discussion by asking their opinion and summarised and generalised the outcomes of the discussion, thereby stimulating the teachers to contribute their own professional expertise.

Next, the teachers developed plans for the context-based inquiry projects. These plans included the development of a concept-related research hypothesis. For example, teachers developed the following hypothesis: 'Wool absorbs more water than cotton, because wool has more intermolecular connections compared to cotton'. While discussing their concept-related research hypotheses, teachers recognised that their students would encounter difficulties when formulating this kind of hypothesis. As Dick stated:

> Tenth grade students are not used to incorporating concepts in their research hypothesis. They have learned to incorporate two different variables in their hypothesis, like, for example, temperature and absorption capacity, but not chemistry concepts.

The teachers agreed on using several different criteria for evaluating these hypotheses, for example, 'a hypothesis cannot be wrong' and 'a hypothesis should connect chemistry concepts with measurable properties of a substance'. James proposed allowing the students to develop a hypothesis first and subsequently discussing the concept-related nature of their hypothesis by applying these criteria. They all agreed to use this general strategy in their classes.

During activity T1, the teachers explored, to a large extent, strategies for teaching the context-based unit. They emphasised the importance of student ownership. In the interaction between the programme and the teachers, the role of the CL proved important in guiding the teachers' discussion and summarising their input thus fulfilling function e.

T1.2: To what extend did the teachers become aware of the differences and similarities between their own views on contexts and the context-based model?

After the teachers had become more acquainted with the context-based unit, the CL encouraged them to discover differences and similarities in their views on context-based chemistry education and the context-based model. First, the CL asked teachers to summarise their views on contexts by using the answers from their pre-programme questionnaire (see Table 3 for teachers' answers). All had difficulties expressing their views on contexts. Secondly, the CL asked the teachers whether the context-based model met with their expectations. Most teachers indicated that it did:

I have not used context-based approaches so far, but this is what I expected from a context-based approach. (Jeremy)

Although the context-based model seemed to be connected to teachers' views (function c), they did not become fully aware of the differences and similarities between their own views on contexts and the context-based model (function d). It appeared to be difficult to guide teachers towards making their views explicit. Thus, function d was not properly fulfilled in the implemented programme.

T2: To what extent did the teachers apply these teaching strategies?

Video recordings from teachers' lessons indicated that their students were amazed by the water absorption of the super absorbents, and that they all enthusiastically formulated questions. In addition, these video recordings showed that all teachers discussed (a selection of) questions with their students, and that some questions were collaboratively reformulated. Furthermore, all teachers indicated to their students that these (reformulated) questions would be answered through the teaching of the remainder of the unit. While teaching the chemistry concepts, video recordings showed that all teachers referred to the students' questions whenever a question could be answered, and students seemed to appreciate the fact that their question was answered in class. The evaluative questionnaires revealed that most teachers provided students with additional curriculum materials and/or taught additional lessons. They deviated from the structure in which chemistry concepts were presented in the unit (moving from the properties of the polymer to its molecular structure), and they taught the chemistry concepts in a more traditional way (focussing on the building blocks of polymers first).

Student products and evaluative questionnaires indicated that many students had difficulties with developing a concept-related research hypothesis. Initially, most hypotheses did not contain chemistry concepts. Audio recordings from tutorial conversations showed that all teachers had to assist their students with the development of chemistry concepts and that they had applied the criteria developed in the previous programme activity. For example, when Clive was confronted with two students who developed a hypothesis about the absorption capacity of different fabrics, he asked the students to explain the differences between absorption capacities of several fabrics with differences in their molecular structures. When one of the students started to compare the number of oxygen atoms in the different molecular structures, as an indicator of the number of hydrogen bonds between the molecules, Clive indicated that they were on the right track.

These findings show that the programme provided the teachers with focused opportunities to apply their teaching strategies. Their orientation (phase T1) led to an classroom application through the use of student questions and the structured tutoring. Meanwhile, many teachers contributed their own ideas on how the sequence of chemistry concepts should be adapted in their teaching and how they should support their students when they had difficulties formulating concept-related research hypotheses.

T3.1: To what extent did the teachers elaborate strategies for teaching context-based units?

The CL engaged the teachers in a discussion about strategies for teaching a context-based unit similar to the context-based unit about super-absorbing diapers. The CL ensured that, when a teacher mentioned a strategy, the other teachers understood the strategy, agreed on the effectiveness of the strategy, and that the strategy did not contradict other strategies. The discussion resulted in a list of do's and don'ts, for example:

- Do: Respond to questions positively.
- Don't: Reformulate questions yourself.
- Do: Maintain a specific theory related criterion like 'you need to mention chemistry substances.'
- Don't: Play the expert during supervision.

Most teachers (Peter, Michael, Clive, Jeremy James and Roger) indicated that they considered this elaboration of the strategies useful for their teaching practice. As Clive wrote in his reflective questionnaire during the third meeting:

> Carefully focusing the questions is very important; I would like to experiment further with this way of teaching.

To a large extent, teachers elaborated strategies for teaching a context-based unit. Also, the planned interaction with the teachers was successful in fulfilling the functions g, h and i. Teachers acquired an overview of how to teach a context-based unit and were equipped to teach such a unit. They also became confident to teach a context-based unit teaching.

T3.2: To what extent did the teachers feel confident in teaching such a context-based unit?

From the reflection phase T3 some typical teacher statements are presented with the inferred category indicating teacher confidence - decision-making, autonomy and self-efficacy.

All teachers were satisfied with the quality of the questions their students formulated, and were enthusiastic about their teaching experience in the context-based introduction. For example, Dick and Peter reported during the third meeting:

> I really liked the approach, and my students are very enthusiastic about the introduction. (Dick, self-efficacy)

> It is satisfying that I could refer to some relevant student questions during the teaching of the chemistry concepts. (Peter, self-efficacy)

Furthermore, all teachers indicated that they considered themselves sufficiently prepared to teach the introduction of the context-based unit and to use student questions in their teaching of concepts. As Sean stated during the third meeting:

> I am going to use this approach [students questions] when teaching other topics. (autonomy)

In a subsequent discussion about reformulating student questions in practice he re-emphasised that reformulation away from the student question may defeat the purpose of context-based teaching by adding:

> (...) but if students do not recognise their reformulated questions, the idea behind the context-based introduction would not work anymore. (self-efficacy)

All teachers agreed with his point of view.

Teachers adapted the units' chemistry concepts because they considered them to be 'too fragmented and insufficient' (Sean) for students to understand and explain properties of super absorbents through its molecular structure. Also, most teachers became aware of the tension between the sequence of concepts of conventional textbooks they were accustomed to, and the reversed sequence of concepts in the context-based unit.

With respect to the concept-based inquiry projects, none of the teachers were satisfied with the concept-related research hypotheses. They felt they had to force their students to use the chemistry concepts and connect these with properties of the substance they wanted to investigate. They considered applying concepts in hypotheses too difficult for their students, even with the additional lessons on chemistry concepts that most teachers provided. For example, Michael stated that:

> Forcing students to use chemistry concepts in their hypothesis does not make them realise the need for studying these concepts, the inquiry projects need to be reconsidered. (decision-making)

The other teachers agreed, and they proposed to have students explain the results of their research with chemistry concepts.

In summary, all teachers reflected on their teaching experience, and their remarks indicated self-efficacy, involvement in decision-making and autonomy. The teachers proposed to adapt the strategy of generating concept-related research hypotheses and sequencing the chemistry concepts. The interaction revealed what the teachers thought about finding solutions for these issues in context-based teaching.

D1: To what extent did the teachers use their teaching experience to explore strategies for designing context-based units?

We expected that Activities T1 to T3 would give teachers an initial understanding of the context-based model in terms of design strategies for new context-based units (see Table 4).

However, teachers did not explicitly explore these design strategies, and therefore, this activity did not fulfill function j and k.

D2: To what extent did the teachers apply these strategies in designing an outline of a new context-based unit?

All teachers applied the design strategies (Table 4) in their justification for selecting one of the four pre-selected context-based introductions (hydrophobic sand, dissolving of polyvinyl alcohol, polyurethane foam and acid coagulation of milk). For example, they all agreed that the hydrophobic sand experiment lacks a clear connection to the students' everyday lives, and that the dissolving of polyvinyl alcohol in water was slow and unclear. In addition, all teachers agreed that the acid coagulation of milk is likely to raise many questions and has a relevance to students' lives. The polyurethane foam, on the other hand, might impress students, but has some practical limitations. Some teachers also considered chemistry concepts that could be connected to these introductions

Table 4: Expected design strategies for new context-based units.

Part of the context-based model	Design strategies
Context-based introduction	Provide for a connection with chemistry concepts
	Connect to students' daily lives
	Generate numerous questions
	Select questions which are practically feasible
Chemistry concepts	Start with an explanation of chemistry concepts
	Zoom into more detailed chemistry explanations
Context-based inquiry projects	Have a strong connection with previous chemistry explanations
	Projects should be practically feasible

> To hydrophobic sand, you could only connect theory about hydrogen-bonding. (James)

> The concepts connected to the acid coagulation of milk are very far away from the students' knowledge. (Roger)

After discussing which introduction was most suitable, both the dissolving of polyvinyl alcohol and the hydrophobic sand were rejected because these introductions were hardly connected to students' everyday lives. The polyurethane foam experiment was eventually rejected because of a lack of practical feasibility. Therefore, the acid coagulation of milk was chosen as a context-based introduction.

All teachers selected relevant chemistry concepts, such as the structure of casein, iso-electrical points and coagulation of proteins, using their own textbooks and a college textbook on biochemistry. Subsequently, the teachers sequenced their concepts similarly to those in the pre-developed context-based unit. They started with the larger structures of milk (colloids and micelles) and then focused on the interactions between these particles, delving further into the structure and properties of proteins (e.g. their iso-electrical points). Based on the teachers' initial choice of context, a 'coconut cheese' inquiry project was presented to them, and they were asked to formulate a concept-related hypothesis. All teachers formulated a concept-related hypothesis, and they investigated whether the selected chemistry concepts were sufficient to verify their hypotheses.

Although the teachers did not explicitly address the design strategies, they applied these strategies while designing an outline of a new context-based unit, so during this activity functions k and l were fulfilled.

D3.1: To what extent did the teachers elaborate strategies for designing context-based units?

Because of time constraints in the fifth meeting, activity D3 was not carried out as planned. Teachers completed the reflective questionnaire, but their responses were not discussed. Instead, teachers' remarks from the questionnaires and their statements in the post-programme interviews are used to answer this sub-question.

The strategies elaborated by the teachers focused on the sequencing of the chemistry concepts, and on connecting these chemistry concepts with both the context-based introduction and the inquiry projects. For example:

> The context-based introduction needs to intrigue students in such a way that it generates a lot of questions. These questions should lead to inquiry projects and to a need to know. (Peter)

> The connection between the inquiry project's context-based introduction and the chemistry concepts needs to be strong. Students need to be able to use these concepts to formulate hypotheses. (Dick)

> The structure of the chemistry concepts is specific to the context-based introduction which is used. (Sean)

To a large extent, the teachers elaborated specific and feasible strategies for designing. Their remarks indicate a deeper understanding of the way (parts of) the context-based model can be used in their teaching and in the design of a unit, and in communicating with other teachers. The data show that the teachers' participation in the programme was successful in fulfilling the functions m, n and o.

D3.2: To what extent did the teachers feel confident in designing a new context-based unit?

Typical teacher statements are presented together with the inferred category of teacher confidence, i.e. involvement in decision-making, autonomy and self-efficacy. During the design activity, all teachers were aware that they did not create a new context-based introduction from scratch, and they acknowledged this as a crucial yet difficult step in designing a context-based unit. In order to design such a new context-based unit, they suggested working as a group, and requiring appropriate resources, preliminary ideas on a 'need to know' problem and ideas about an inquiry. Teachers' statements below illustrate these views:

> It is impossible to do this myself (...) when I am not provided with time and resources. (Peter, autonomy)

> Different people working together have varying ideas and evoke questions which you would not have thought of on your own. (Michael, self-efficacy)

All teachers had reservations about designing new context-based units from scratch. However, they intended to implement the context-based model and to use parts of this model in their teaching practice, as illustrated by Roger's statement below:

> Using student questions was completely new for me; I never did this before. I was pleasantly surprised by the quality of the questions my students wrote down (...) I will use this strategy more often in the future, for example, in the ninth grade when I teach the topic of acids and bases. I also want to let my students formulate hypotheses in their inquiry projects but initially without incorporating chemistry concepts. (decision-making)

Teachers' remarks indicated high levels of self-efficacy, autonomy and involvement in decision-making on most aspects of the design of context-based teaching. As a result of the participation in the programme, the teachers felt confident in designing an outline of a new context-based unit.

Conclusions and discussion

This study sought to investigate the process of empowerment of chemistry teachers for context-based design through participation in a professional development programme. The research question that guided this study was: To what extent does the refined professional development framework empower chemistry teachers for designing context-based chemistry education? The results show that, to a large extent, the refinement of the proposed framework initiated empowerment in some aspects. Teachers showed professional growth: Their understanding of the nature of the context-based curriculum innovation increased and their ability to carry out their new role improved. They also experienced personal growth: They acquired high levels of confidence in decision-making, autonomy and self-efficacy. However, the teachers argued that this is limited to a situation in which they could work in a group and have resources and access to preliminary ideas on 'need to know' problems and ideas about inquiry projects.

The implemented professional development programme functioned well: 13 out of 15 functions were fulfilled. Three factors had a major influence on the fulfilment of the functions. These factors were: The input of teachers' professional knowledge, the programme's designing activities, and the curriculum leader.

The input of teachers' professional knowledge was apparent in the discussion of the adaptations of the context-based unit (activities T1-T3). The findings showed that teachers suggested the need for careful reformulating students' questions in order to ensure student involvement in the unit, altered the structure and sequence of the chemistry concepts, and proposed adaptations to context-based inquiry projects. The input of teachers' professional knowledge contributed to the fulfilment of function e. In addition, the results also revealed that, teachers had difficulties with explicating their views on context-based education. Although, the tacit and localised nature of teachers' professional knowledge might have hindered fulfilment of function d, the teachers did became aware of their difficulties.

Based on the results of the first research cycle, the design activity (D2) was revised from designing an appropriate context-based introduction matching pre-selected concepts into selecting a suitable context-based introduction from a given set of introductions, and finding suitable concepts for it. In other words, the design activity became more structured and closed. During the orientation on designing context-based units (D1), strategies for designing context-based units were not explicitly described or explored (function j). However, the results showed that teachers were able to design an outline of a new context-based unit. It can be concluded that without an explicit orientation on design strategies (function j), the design activity contributed to the fulfilment of function l.

The findings also revealed that the CL had a large influence on the fulfilment of the functions. During activity T1, he encouraged teachers to contribute their own professional expertise (function e). Also during activity T1, the CL ensured that, teachers' personal goals were made explicit and acknowledged, so the discrepancies between the goals of the programme and teachers' personal goals had no repercussions for teacher participation (function b). He also acknowledged their input and ensured progress by carefully guiding and focusing activities and group discussions.

From the findings, it can be concluded that the input of teachers' professional knowledge and the active role of the CL enriched the implementation of the programme, and contributed to teacher empowerment. However, the revised designing activity provided teachers with little opportunity to bring in their professional knowledge that are much more focused on teaching than on designing. Although strategies for designing context-based units were applied and elaborated, teachers neither discussed these strategies nor were they explicitly described, e.g. written down as do's and don'ts. These findings do not provide an answer to the question: to what extent can the teachers effectively apply their learning outcomes without support in other environments (e.g. in their own classrooms or in teacher networks without a CL) and can they come up with 'need to know' contexts without support?

We addressed in this study three problems we found in the previous study, making the following changes to the framework and programme: (a) we incorporated instructional functions into the framework, (b) we incorporated 'students' questions' and 'concept-related hypotheses' into the pre-developed context-based unit, and (c) we restructured the design of the outline of the context-based unit. From the analysis of the data we may conclude that these changes were to a large extent successful in enhancing the quality of the framework and the programme.

These conclusions lead to the following recommendations. Firstly, at the start of the programme the goals of the programme should be carefully aligned with the goals of teachers through an extensive dialogue between the teachers and the CL. The context-based curriculum innovation could be discussed, articulating personal beliefs on context-based chemistry education, and creating a 'common platform' about the goals, contents and procedures of the programme. Secondly, the design activities should start with explicating and discussing teachers' professional knowledge about designing curriculum materials. Instead of selecting from a pre-selected set of 'need to know' contexts, the teachers could be provided with resources from which they could elicit suitable contexts themselves. More time seems to be needed for these activities (Voogt et al., 2011). Thirdly, the framework should emphasise more strongly the nature and impact of the teachers' professional knowledge on the process of empowerment for context-based designing. Finally, the framework should also acknowledge the important role of the CL. It needs to provide CLs with general guidelines on how to capitalise on the professional knowledge of the teachers and how to recognise their input during the implementation of the programme.

The usability of the framework for structuring other teacher empowerment processes is subject to several restrictions. Firstly, our study on the framework was carried out in the initial stage of a curriculum innovation. The programme was designed and carried out at the time when the curriculum innovation became official governmental policy. Whether the framework is applicable in other stages of the curriculum innovation (Bulte & Seller, 2011), requires further investigation. Secondly, the results are based on seven chemistry teachers only. These teachers are likely to be not representative for the majority of the chemistry teachers in the Netherlands (Van Driel et al., 2005). Thirdly, the framework was studied in a context-based innovation in chemistry education. Further research is needed to evaluate the applicability across other science domains (e.g. biology, physics) and across other kinds of innovations aiming at meaningful student learning (e.g. inquiry-based, STS).

We have demonstrated that this professional development framework can be applied in designing a programme for teacher empowerment, and that it can also be used to investigate the process of teacher empowerment. Investigating the process of empowerment provided valuable insights, such as the interplay between the programme's activities, the role of the CL and teachers' professional knowledge. Also, it provided a deeper understanding of the difficulties of empowerment of teachers for their new role in an upcoming curriculum innovation. Contemporary frameworks focus on describing teacher development, or on designing a professional development programme (Hewson, 2007). Our framework integrates both aspects, providing principles for designing and evaluating development programmes and providing a description of the professional development processes that are expected to take place. This study marks a first step toward identifying how chemistry teachers' professional development processes are initiated and evaluated using a coherent professional development framework in a context-based curriculum innovation.

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	Chapter 1 **Introduction and overview** General research question: What constitutes a professional development framework for designing and evaluating a programme to empower teachers for context-based chemistry education?

First Research Cycle	**Chapter 2** **Towards a professional development framework: Goals, strategies and rationale** In this chapter the goals and strategies are presented for a professional development framework for designing and evaluating a programme to empower chemistry teachers for context-based education. **Chapter 3** **Towards a professional development framework: Learning theory and synthesis** This chapter describes the synthesis of a learning theory, goals and strategies in a framework for professional development to empower chemistry teachers for context-based education. **Chapter 4** **Evaluation of a professional development framework to empower chemistry teachers for context-based education** This chapter describes an elaboration of the framework into a programme for professional development. The enactment and evaluation of the programme with a group of experienced chemistry teachers are presented.
Second Research Cycle	**Chapter 5** **Evaluating a refined professional development framework to empower chemistry teachers for context-based education** This chapter considers the refined framework and its elaboration into a new programme. The enactment and evaluation of the new programme with a new group of experienced chemistry teachers are described.

	Chapter 6 **Conclusions and reflection** This chapter summarises all major findings and conclusions of the study. It reflects on the both the findings and the research method.

Chapter 6

Conclusions and reflection

Introduction

The aim of the research described in this thesis is to acquire more understanding of the contribution of the activities in a teachers' professional development programme which leads to their empowerment for context-based chemistry education. At a more general level, it aims to contribute to the knowledge base on how to design and evaluate professional development programmes for context-based curriculum innovations. The knowledge involved in this research will be captured in a framework. The general research question addressed in this thesis is:

> *What constitutes a professional development framework for designing and evaluating a programme to empower chemistry teachers for context-based education?*

This chapter summarises all major findings and conclusions in the studies, followed by a critical reflection on the professional development framework. A discussion of the relevance and meaning of the professional development framework is presented. Finally, the general research question is answered, and implications are formulated for the researchers, teacher educators and policymakers for whom the results of the research described in this thesis are expected to be relevant.

The framework

To design and evaluate a programme to empower teachers for a context-based and teacher-based curriculum innovation, an adequate professional development framework is needed. Such a framework should consist of goals for the programme, professional development strategies and a sequence of events to accomplish these goals (Chapter 2), and learning theory to describe the professional development process (Chapter 3).

Review of literature on context-based and teacher-based curriculum innovations resulted in the following goals (Chapter 2):
- Teachers understand the use of contexts in chemistry education.
- Teachers are able to teach and design context-based chemistry education.
- Teachers feel confident about their new roles as teachers and designers of context-based chemistry education.

With these goals in mind, literature on professional development of (science) teachers, was reviewed and four suitable strategies for their professional development were indentified (Chapter 2):

- Teaching a pre-developed innovative unit.
- Reflection on practical experiences.
- Collaboration with peers.
- Designing an outline of a new innovative unit.

To investigate how these strategies can be incorporated into a professional development programme, an informed selection of studies in which professional development programmes were designed and evaluated was reviewed (Chapter 2). The review resulted in a sequence of events which can be used for collaborative teacher-based curriculum design:
- Create a common platform about the aims and procedures for design by exchanging teachers' personal beliefs and opinions about the characteristics of the curriculum units to be designed.
- Design and discuss innovative units.
- Enact these units in the classroom.
- Reflect on classroom experiences, and modify the units accordingly.
- Reflect on the design process.

Furthermore, it was concluded that the way in which the strategies were transformed into specific activities remained unclear, and that the contribution of these activities to the learning outcomes received little attention. This lack of attention to the professional development process was attributed to the absence of an underlying coherent description of the professional development process. In order to investigate the process of professional development during a programme and to investigate the contribution of the programme's activities to teachers' professional development process, it was concluded that the professional development framework should also involve a description of the process of teacher professional development.

After a review of the literature about teacher knowledge and beliefs and several different perspectives on learning, a suitable learning theory for a description of the process of teacher professional development was identified. Galperin's theory of the internalisation of actions (Chapter 3) provided a useful description for the intended professional development process. The goals, strategies, events and Galperin's theory were synthesised into a professional development framework (see Figure 1).

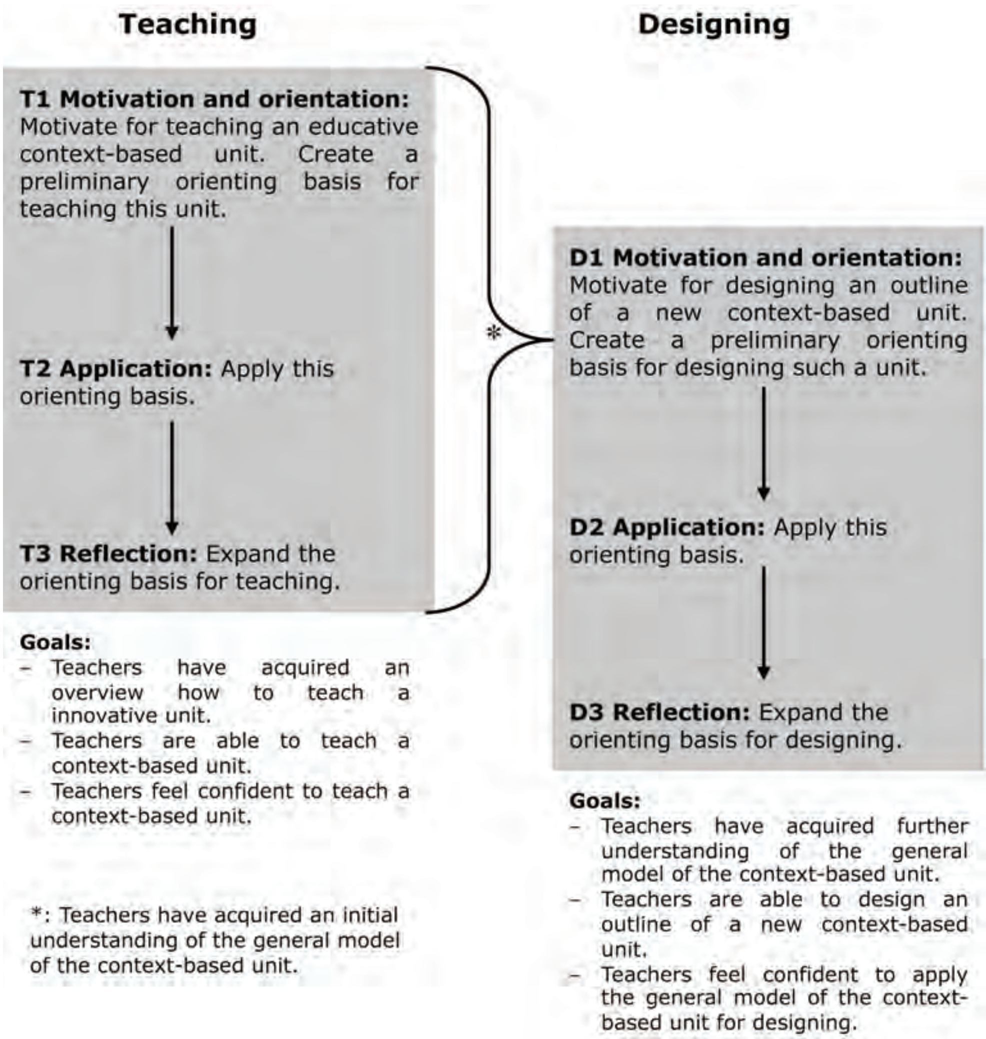

Figure 1: Professional development framework used in the first research cycle.

Design and evaluation

The professional development framework (see Figure 1) was used to design and evaluate a programme (Chapter 4). All selected teachers were motivated to teach the pre-developed context-based unit, and they all designed new teaching strategies, which aimed, amongst others, to solve the 'need to know' problem that was considered an important aspect of the context-based unit. After teaching the unit, it became clear to the teachers that their strategies did not solve the 'need to know' problem.

Teaching **Designing**

0 Create conditions for empowerment
a. Motivate teachers.
b. Clarify learning goals.
c. Connect to teachers' views on context-based chemistry education.

T1 Orientation: Create a preliminary orienting basis for teaching a context-based unit.
d. Let teachers discover differences and similarities among their views on context-based chemistry education and the context-based unit.
e. Show how to teach the context-based unit, give examples and present conditions for use.

T2 Application: Apply this orienting basis.
f. Provide the opportunity to apply the knowledge and skills in practice.

T3 Reflection: Expand the orienting basis for teaching.
g. Give teachers the opportunity to reflect on their teaching and learning experiences.
h. Examine the learning results by creating the opportunity for teachers to produce a product.
i. Evaluate the learning results.

Goals:

- Professional growth: The teachers have acquired an overview of how to teach a context-based unit and the teachers are able to teach a context-based unit.
- Personal growth: The teachers feel confident to teach a context-based unit (involvement in decision-making, autonomy and self-efficacy in teaching).

*: Teachers have acquired an initial understanding of the general model of the context-based unit.

D1 Orientation: Create a preliminary orienting basis for designing a new context-based unit.
j. Let teachers discover differences and similarities among their views on designing context-based chemistry education and design of the context-based unit.
k. Show how to design context-based units, give examples and present conditions for use.

D2 Application: Apply this orienting basis.
l. Provide the opportunity to apply the knowledge and skills in practice.

D3 Reflection: Expand the orienting basis for designing.
m. Give teachers the opportunity to reflect on their design and learning experiences.
n. Examine the learning results by creating the opportunity for teachers to produce a product.
o. Evaluate the learning results.

Goals:

- Professional growth: The teachers have acquired a deeper understanding of the general model of a context-based unit and the teachers are able to design an outline of a new context-based unit.
- Personal growth: The teachers feel confident to use the general model of a context-based unit for designing (involvement in decision-making, autonomy and self-efficacy in designing).

Figure 2: Refined professional development framework used in the second research cycle.

During the design of an outline of a new context-based unit, all teachers encountered difficulties in designing a motivating context-based introduction and appropriate inquiry projects for the students starting from specific chemistry concepts. Teachers noticed that their preliminary orienting basis for design was not suitable for designing new context-based units, and needed to be expanded. From the results of this first research cycle, it was concluded that teachers were only partly empowered for context-based chemistry education. Overall, the results made it clear that the phases and strategies from the framework did not provide sufficient guidance for designing the programme's activities, and that the framework needed to be refined. In addition, it was concluded that the pre-developed context-based unit used in this first research cycle needed revision.

The evaluation resulted in several modifications of the unit, the framework and the programme (Chapter 5). First, to solve the 'need to know' problem, the pre-developed context-based unit was revised by restructuring its chemistry concepts, and by incorporating 'students' questions' and 'concept-related hypotheses' into the unit. Second, in the revised design activity teachers started from a pre-selected set of context-based introductions, rather than from specific chemistry concepts. In other words, the design activities became more structured and closed. Finally, instructional functions were incorporated into the framework. These instructional functions resulted in a refined professional development framework. This refined framework (see Figure 2) was used to design and evaluate a revised programme. The evaluation in the second research cycle focused on changes made to both the framework and the programme.

The results show that, to a large extent, the revised programme initiated teacher empowerment for context-based chemistry education. Teachers grew professionally: their understanding of the nature of the context-based curriculum innovation improved and they were able to carry out their new roles adequately. They also experienced personal growth: feeling confident in decision-making, autonomy and self-efficacy. The teachers argued, however, that this was restricted to situations in which they could work in a group and have resources and access to preliminary ideas on 'need to know' problems and ideas about context-based projects.

The findings indicated that the revised context-based unit supported teachers in engaging students in questions and made them aware of the usefulness of using student questions to connect a context with concepts. Teachers questioned the new sequence of the chemistry concepts, however, and they considered that formulating concept-related research hypotheses was too difficult for their students. Although the revisions improved the context-based unit to a certain extent, it can be concluded that the revised context-based unit did not provide a robust solution to the 'need to know' problem. The results also showed that with the revised design activity the teachers were able to design an outline of a new context-based unit. The structured and closed nature of the design activities raises the question whether teachers can come up with 'need to know' contexts without support from a pre-selected set of examples.In general, the implemented professional development programme functioned well and 13 out of 15 functions were fulfilled. The findings indicated the input of teachers' professional knowledge, the programme's design activities and that the curriculum leader had a major influence on the fulfilment of the functions. It can be concluded that the input of teachers' professional knowledge and the active role of the CL enriched the implementation of the programme and contributed to the teachers' empowerment. The revised design activities, however, provided teachers with little opportunity to apply their professional knowledge. Although strategies for designing context-based units were applied, teachers did not explore these strategies during the orientation (functions j and k in Figure 2). In the second research cycle, the three problems which emerged from the first research cycle were addressed, resulting in a revised framework and a revised programme. From the analysis of the data it can be concluded that these revisions enhanced the quality of the framework and the programme.

Reflection

In this section, the findings on several aspects of the framework are discussed before the conclusions are formulated in the next section. First the context-based model and unit, and the role of the curriculum leader are discussed, followed by a reflection on the orientation on designing. Finally, the use of the framework for research on and design of teacher professional development programmes are discussed.

Context-based model and unit

Both the context-based model and the pre-developed context-based unit play an important role in the framework (Figure 2). One of the underlying assumptions of the framework is that the context-based unit is a high-quality, educative unit, which provides a solution to the 'need to know' problem when designed according to the context-based model. Another assumption is that teaching such a context-based unit provides teachers with information about the context-based model. Such information could support them when designing an outline of a new context-based unit. The framework, however, neither specifies which context-based model should be used nor specifies criteria for choosing a suitable model. In the first research cycle, a specific context-based model was selected because the Eenhoorn Group advocated the use of that context-based model to design context-based units (Chapter 1) and because, at that time, the only available context-based unit was designed according to this model. Findings from both research cycles showed that the teachers experienced difficulties with teaching the context-based unit. More specifically, they had difficulties with incorporating the 'need to know' in the context-based unit on super-absorbents and with designing a motivating context-based introduction, and appropriate inquiry projects. Teaching the context-based unit, however, did make teachers aware of the 'need to know' problem and the difficulties with it.

Findings from both research cycles have shown that neither this context-based model nor this context-based unit provided a solution to the 'need to know' problem. This context-based model also failed to support teachers sufficiently when they were designing an outline for a new context-based unit. A similar result was reported by Bulte, Westbroek, De Jong, & Pilot (2006), who implemented and evaluated a module on water quality, developed according to this context-based model. They concluded that:

> 'The three-phase framework [the context-based model] (...) was not adequate for its purpose. It did not induce in students a coherent flow of "need-to-know" at the moment the students were to extend their knowledge. The intended (context-independent) concepts (...) only became meaningful afterwards during the intended application of these concepts, and was not planned on a "need-to-know" basis from the perspective of students' (Bulte et al., 2006, p. 1071).

To incorporate a coherent 'need to know' in context-based units, these authors proposed an 'authentic practice' as an alternative model for context-based chemistry education. Several case studies have been conducted which use authentic practices to develop context-based units. These studies have shown that with this alternative model the previously reported problems with the old model and unit can be circumvented (Westbroek, Klaassen, Bulte & Pilot, 2010; Prins, Bulte & Pilot, 2011).

Although the context-based unit did not provide a solution to the 'need to know' problem, findings from both research cycles indicated that the context-based unit did contribute to teachers' empowerment for context-based chemistry education (Chapters 4 and 5). In general, a context-based unit should not only be high-quality and educative but should also create constructive friction (Vermunt & Verloop, 1999) among teachers. Their knowledge and beliefs are challenged, stimulating them to reconsider their existing views and practices. For the friction to be constructive instead of destructive, the implementation and evaluation of a context-based unit should be supervised by a competent curriculum leader.

Curriculum leader

The curriculum leader (CL) is not explicitly mentioned in the framework. Findings from the second research cycle (Chapter 5) showed that the CL contributed substantially to the empowerment of the teachers. These results indicated that the CL played different roles during the implementation of the programme. These roles can be described as:

- Seeking 'common ground' when the CL makes teachers' personal goals explicit and acknowledges these goals. This role is especially important during the phase in which the conditions for empowerment are created.
- Hunting for 'treasures' when the CL encourages teachers to contribute their professional expertise to the group, especially during the reflection phases.
- 'Catalysing' when the CL stimulates group discussions by introducing his/her own opinion, trying to convince the teachers or be convinced by their arguments, and when the CL carefully guides and focuses programme activities.
- Keeping an overview when the CL leads the programme into which all the activities of the teachers have to fit.

These roles are equivalent to the roles identified by Deketelaere and Kelchtermans (1996) in a study on supervising a teacher design team. An effective CL should be able to play these different roles, and understand when to play them during the implementation of the programme.

In addition to these roles, the findings from both research cycles also indicate that an effective CL should have a thorough understanding of the nature and the design of the programme. In both research cycles (Chapters 4 and 5), the CLs, who were experienced chemistry teacher educators, participated in the research team which designed, planned and evaluated the programme. Through their involvement the CLs not only became acquainted with the nature and the design of the programme, but their involvement also provided them with the opportunity to contribute to the programme and to develop a sense of ownership of the programme. Also, they became more aware of the critical activities in the programme and they felt comfortable about deviating from the planned programme when appropriate, without causing serious changes in the programme (Brown & Campione, 1996). It can be concluded that the important contribution of the CL to the empowerment of chemistry teachers for context-based education should be acknowledged in the framework. Because of the focus of the research on the teachers and the programme, the role of the CL and his/her contribution to the empowerment of teachers was not investigated thoroughly.

Orientation on designing

An important characteristic of the framework is the orientation on designing an outline of a context-based unit. It was assumed that teaching a pre-developed context-based unit would be a suitable orientation on designing an outline of a new context-based unit (Figure 2). Results from both research cycles indicate that teaching the context-based unit contributed to teachers' motivation for and understanding of context-based chemistry education but they had difficulties in creatively designing an outline of a context-based unit. Furthermore, findings from both research cycles showed that at the beginning of the programme several teachers did not see the point of designing an outline of a context-based unit. They joined the programme because of the chance to explore and teach the context-based unit on super-absorbents (Chapters 4 and 5). Although teaching a pre-developed context-based unit is a powerful strategy for teachers to become empowered for teaching context-based chemistry education, it can be concluded that teaching a context-based unit on super-absorbents does not provide teachers with an appropriate orientation on designing an outline of a new context-based unit.

The orientation on designing used in this research project differs from other teacher design networks (Voogt et al., 2011). These networks generally design new curriculum materials followed by teaching and evaluation of these materials. During the design of the curriculum materials, these networks generally make use of exemplary, pre-developed curriculum materials. These materials are used to provide teachers with an image of the change that is intended and help the teachers to define the goals and the design activity (Chapter 2). Designing new curriculum materials with the aim of teaching and evaluating them is likely to provide teachers with a sense of purpose for the design activities. A sense of purpose is considered an important condition for learning (Lijnse & Klaassen, 2004). Teachers are more likely to learn when they can apply the results of their learning directly in their teaching practice. To accomplish such a sense of purpose and to provide teachers with an appropriate orientation on designing, it should be considered in a further development of the framework that:

- Teachers and the CL should create a shared vision for teaching and designing context-based chemistry education (Chapter 5).
- Teachers should have an opportunity to teach and collaboratively evaluate their newly designed materials (Voogt et al., 2011).
- Teachers should be provided with resources from which they can elicit suitable contexts themselves (Chapter 5).

Whether these strategies would contribute to a sense of purpose among teachers for designing an outline of a context-based unit could be the subject of further study.

Professional development framework

The aim of the research described in this thesis was to investigate the contribution of the activities in the programme to teachers' process of professional development which leads to their empowerment for context-based chemistry education. The process of teacher professional development is incorporated in the framework. From the findings of both research cycles, it can be concluded that the main activities of the programme, teaching a pre-developed innovative unit and (collaboratively) designing an outline of a new innovative unit, contributed to the professional development process of teachers. In general, teaching the context-based unit contributed to teachers' motivation for and understanding of context-based chemistry education, but it also made them aware of the difficulties surrounding teaching 'need to know principle'. Designing an outline of a context-based unit made teachers aware that they had difficulties with creatively designing a new context. These findings, however, also showed that the actual professional development deviated from the expected professional development, and that the current framework did not sufficiently take the role of the CL and the professional knowledge of teachers into account. The extent of the contribution, however, depends not only on the way these activities were elaborated in the programme, but also on teachers' beliefs, knowledge and attitudes about chemistry education and professional development. Little can be said about the extent in which activities have contributed to the professional development process of individual teachers. Investigating changes in knowledge and beliefs of individual teachers and investigating whether teachers participated in such a design group was beyond the scope of the research described in this thesis.

To investigate the contribution of the activities to teachers' professional development, sub-questions were used which focussed on the goals and outcomes of the programme's activities. These sub-questions were answered by means of analyses of audio- and videotapes of these activities, of teacher products from these activities and of teacher interviews before and after the programme. In the first research cycle, the sub-questions provide a strong focus on the (expected) professional development process. In the second cycle, however, it became clear that these sub-questions actually hindered observations of the professional development process, because other learning processes which did not fit into these sub-questions were happening.

Related to the contribution of the activities to teachers' professional development is the persistence of the outcomes of the professional development process. According to Penuel, Fishman, Yamaguchi & Gallagher (2007) such outcomes are more persistent and enduring when the programme is succeeded by teacher support and follow-up meetings. These strategies are not part of the framework. The aim of the framework, however, was to prepare teachers for participating in a design group which is part of the context-based curriculum innovation described in Chapter 1. It is likely that the outcomes are more persistent when teachers join such a design group, because these groups will provide collaborative support and follow-up. When teachers return to their daily practice without support and follow-up it is likely that these outcomes will disappear.

The designing of the framework and the programme is a complex process which involved many decisions on activities, tasks, interactions and facilities. The framework engendered many strong arguments regarding the design and elaboration of the programme. Other arguments will also have influenced decisions, explicitly or implicitly, and certainly not all of these have been described in the research papers and this thesis. Other arguments might have led to other decisions and programmes that achieved the aims equally. The activity of designing is based on functionality, which means that other means might also lead to the same results. According to Borko (2004) there are four key elements that make up a professional development system. These are the teachers, the facilitators (the CLs), the programme itself and the context in which the professional development occurs. To improve the feasibility of the framework, it needs to be examined in more case studies, not only with a new group of teachers, a different CL or within a new (context-based) curriculum innovation, but also with a new team of researchers-developers which should design, implement and evaluate a new programme with the framework. In addition, the teachers should have a major role in the actual elaboration of the programme. Research on co-design and participatory design (Spinuzzi, 2005) has shown the substantial impact on the final design of new products when users are actively involved in the design process. A new team of researcher-developers and input of teachers during the design of the programme, are likely to contribute to the explication of the design of the programme and to the feasibility of the framework.

Conclusions

The outcomes of the four studies as described in the previous chapters have produced an answer to the general research question of what constitutes a professional development framework for designing and evaluating a programme to empower chemistry teachers for context-based education.

It was argued that a framework for designing this kind of professional development programmes consists of a specific sequence of strategies: teaching an innovative context-based unit, followed by designing an outline of a new context-based unit. Teaching a pre-developed context-based unit which focuses on strategies to connect contexts with chemistry concepts provided teachers with an understanding of the use of contexts in chemistry teaching. Collaboratively designing an outline of a new context-based unit provided teachers with the opportunity to apply their knowledge on contexts in a design activity, and gave them confidence to participate in a design network. To design and investigate the programme of teacher professional development, a framework should consist of phases which describe the intended professional development process during these strategies, and instructional functions which provide guidelines to design actual activities for each phase of the programme. The framework did not take into account, however, the role of the curriculum leader or the stage of the curriculum innovation in which the framework is used. Nor does the framework explicitly describe the use of the professional knowledge of participating teachers.

Limitations

The findings in these studies are to a certain extent unique to the setting in which this research was carried out. Both research cycles were carried out during the initial stage of a context-based curriculum innovation. In this stage, the innovation was characterised by the call for discussion by a small group of concerned curriculum stakeholders. In a subsequent stage, the curriculum innovation might become more institutionalised and could involve more teachers and more exemplary context-based materials. Specific characteristics of the stages in the innovation will place specific demands on the professional development of teachers. The framework and its underlying arguments are likely to be valid for other stages of the innovation. In the elaboration from framework to professional development programme for chemistry teachers on context-based education, however, and in the execution of the programme, the stage of the innovation and the specific characteristics of the teachers' situation should be taken into account.

The findings are based on two small groups of teachers and two curriculum leaders. In the first research cycle six teachers participated, and in the second research cycle seven teachers participated. Therefore, caution is needed in generalising the findings. Because the research was carried out in the initial stage of the curriculum innovation, these teachers may have been 'front-runners' in the innovation process and therefore they probably were not representative of the majority of chemistry teachers in the Netherlands.

The limitations of this study also relate to the validity of the analysis of literature on teacher professional development (Chapters 2 and 3) and the analysis of empirical data (Chapters 4 and 5). In Chapters 2 and 3, an informed selection of empirical research papers on teacher professional development was reviewed. For practical reasons, the review of these papers was not carried out with investigator triangulation (Janesick, 2000). In both empirical research cycles (Chapters 4 and 5), the analysis of the empirical data consisted mainly of interpretation of statements from teachers. Several researchers independently analysed the empirical data and compared the results of their analyses afterwards (investigator triangulation). The interpretation of the data was not checked with the teachers, however (participant triangulation). Investigator triangulation in analysis of the literature and participant triangulation in the data analysis would have contributed to the validity of the research and would have improved its credibility and authenticity.

Implications

In this section, the implications of the research described in this thesis are presented for researchers, teacher educators and policymakers.

Researchers

Research is never finished, and often results in new questions. Based on the research described in this thesis, the following issues are valuable for further research. First, research on the use of authentic practices as contexts in chemistry education has shown that the problems with the context-based model and unit, as described this thesis, can be circumvented (Westbroek et al., 2010; Prins et al., 2011). Therefore, it is worthwhile to investigate the consequences of using authentic practices instead of the context-based model in the professional development framework and programme. Second, it would be interesting to investigate whether new strategies (creating a shared vision, teach and evaluate newly designed materials, provide resources for designing new contexts; Voogt et al., 2011) indeed provide a sense of purpose among teachers and contribute to an appropriate orientation on designing. Third, for further understanding of the process leading to teacher empowerment for context-based chemistry education, the roles and expertise of the CL during the design and implementation of the programme should be the subject of further study. Finally, to improve the feasibility of the framework, it needs to be examined in more case studies, not only with a new group of teachers, a different CL or within a new (context-based) curriculum innovation (Borko, 2004), but also with a new team of researchers-developers which should, in collaboration with participating teachers, design , implement and evaluate a new programme. Such an evaluation should be focussed on not only the outcomes of activities but also on the role of the CL and the interaction between teachers and CL, in order to obtain a refined insight in the actual process of teacher professional development.

Teacher educators

It is likely that in the near future many chemistry teachers will be involved in context-based chemistry education (Smith, 2011; OCW, 2012). Activities to empower teachers for context-based chemistry education should not be limited to in-service teachers but be extended to pre-service teachers. Therefore teacher education institutes should pay attention to empowerment of pre-service teachers for context-based chemistry education. Teacher education curricula generally consist of several courses: general educational courses, chemistry education courses, internships and subject matter courses. To empower pre-service teachers for context-based chemistry education, context-based education should be addressed in all of these courses.

First, the chemistry teacher education curriculum should ensure that new teachers learn to understand the key aspects of context-based education in general: the vision and arguments, the design principles and the new content areas. In teaching about these key aspects, general educational courses should not only focus on general educational theory but also on different context-based models (King, 2012). Chemical education courses should provide pre-service teachers with the opportunity to analyse and compare traditional and context-based teaching materials, and teacher educators should teach subject matter courses through context-based units and discuss their course design with their students ('teach as you preach'; Swennen, Lunenberg & Korthagen, 2008). Second, such a curriculum should provide pre-service teachers with specific skills for teaching and designing context-based chemistry education. Small-scale design activities should be incorporated in chemical education courses in which pre-service teachers incorporate contexts into existing teaching materials. During their internships pre-service teachers should have the opportunity to teach context-based materials. Third, the chemistry education curriculum should make pre-service teachers feel confident in their roles as teachers and designers of context-based education. During their courses pre-service teachers should continuously reflect on their experience and discuss the merits and drawbacks of context-based education, constructing their own interpretation of the meaning and use of contexts in chemistry education (Van de Sande, Tielman & Mollen, 2011).

Policymakers

The research described in this thesis has shown that a professional development programme for chemistry teachers on context-based chemistry education contributes to teacher empowerment for teaching context-based chemistry education. It has also indicated that teachers can become empowered for designing context-based chemistry education only if they are provided with sufficient time and resources. This research has shown that two three-hour meetings are barely sufficient to design an outline of a new context-based unit (Chapters 4 and 5). In the light of the research described in this thesis, chemistry teachers should be provided with a two-year professional development programme with regular meetings in order to successfully design, teach and evaluate any new innovative curriculum unit required. Therefore, policymakers are recommended to provide teachers with ample time to participate in such programmes, and to allocate appropriate resources to these programmes.

When the scale of the innovation is increased, more teachers, other then the front-runners, are addressed. Policies should be developed to involve these teachers in the innovation and to interconnect the different stages of the innovation (Bulte & Seller, 2011). First, a new professional development programme should be developed which is tailored to the needs of these teachers. The results from the research described in this thesis could be useful in developing such a programme. Second, front-runners could become curriculum leaders in these programmes. Since most teachers have little experience in coaching their peers, front-runners could be supported in becoming qualified curriculum leaders. Specific activities need to be developed in which experienced curriculum leaders can provide this kind of support. The results from this research might be helpful in the design of such activities.

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Summary

The research described in this thesis focuses on empowering chemistry teachers for context-based education. To prepare teachers for change, educational innovations are usually accompanied by professional development programmes. Research focuses mostly on evaluating the outcomes of these programmes in terms of changes in teacher cognitions, teacher practices or improvement of students' results. Little attention is given to the professional development processes during these programmes. The research described in this thesis aims to acquire more understanding of the contribution of the activities in a programme to teachers' professional development. At a more general level, it aims to contribute to the knowledge base on how to design and evaluate professional development programmes for context-based curriculum innovations. To accomplish these goals, a professional development programme should be designed, carried out and evaluated. The design of such a programme requires a professional development framework with, amongst others, a description of the professional development of teachers. The general research question is: What constitutes a professional development framework for designing and evaluating a programme to empower chemistry teachers for context-based education?

Chapter 2 reports the first step in the synthesis of a professional development framework, identifying suitable goals and appropriate professional development strategies. Literature on context-based curriculum innovations and teacher-based innovations (in which teachers participate in the design of the new curriculum) was reviewed. The review resulted in the following goals: Teachers understand the use of contexts in chemistry education, teachers are able to teach and design context-based chemistry education and teachers feel confident about their new roles as teachers and designers of context-based chemistry education. In addition, the following strategies were identified: Teaching a pre-developed innovative unit, reflection on practical experiences, collaboration with peers and designing an outline of a new innovative unit. Subsequently, the operationalisation of these strategies in professional development programmes was reviewed. A specific sequence of events for designing teaching materials was identified. Also, it appeared that these studies lack a clear relation between goals, strategies and activities. These studies focus mostly on the outcomes of the professional development programmes. There is also little attention for the contribution from

programme's activities to teachers' professional development process. It was concluded that a framework should contain a learning theory which describes the process of professional development.

Chapter 3 presents the second step in the synthesis of the professional development framework, identifying an appropriate learning theory for teacher professional development. Several contemporary learning theories were presented. Based on the goals and strategies from Chapter 2, Galperin's theory for the internalisation of actions was selected. Subsequently, this learning theory was synthesised with the strategies and goals into a framework. The framework consists of a teaching and a designing strand. Each strand consists of three phases, an orientation, an application and a reflection phase. The strands are interconnected, the teaching strand itself is part of the orientation phase of the designing strand. Each strand has goals, in terms of understanding of and feeling confident about teaching and designing context-based chemistry education. This framework could not only be used for designing and evaluating a programme to empower chemistry teachers for context-based education, but also for investigating teachers' professional development during the implementation of the programme.

Chapter 4 presents the design, implementation and evaluation of a programme based on the professional development framework. The programme consisted of teaching a context-based unit on super absorbents in disposable diapers (the context) followed by designing of an outline of a new context-based unit. The contexts in these units aim at evoking students' curiosity and a need for learning specific chemistry subject matter ('need to know'). Six experienced chemistry teachers participated in the programme. The findings indicated that the intended professional development only partly took place and that teachers became only partially empowered for designing context-based chemistry education. Based on the findings, revisions to the framework and the programme are proposed. First, the context-based unit needs to embed teaching strategies, which solve the 'need to know' problem. Second, teachers need more support while designing an outline of a new context-based unit. Third, the framework should provide more specific guidelines for the design of an effective programme for professional development.

Chapter 5 reports the refined professional development framework, its elaboration into a revised programme and the implementation and evaluation of the programme. The programme and the framework were revised on three aspects. First, teaching strategies were incorporated into the context-based unit on super absorbents in disposable diapers which could solve the 'need to know' problem. Second, the design activity was adapted in such a way that teachers could choose a suitable context-based introduction from a pre-selected set. Third, the framework was refined with instructional functions to provide guidelines to design and plan the programme's activities, and to make these activities more effective and transparent. The revised programme was implemented with seven new chemistry teachers and a new curriculum leader. The evaluation of the programme focused on the revisions made to the programme, and on the outcomes regarding the professional development of teachers. The findings showed that, to a large extent, the refined programme initiated teachers' empowerment for teaching and designing context-based chemistry education. However, the teachers argued that this is limited to a situation in which they could work in a group and have sufficient time and access to resources. The findings also showed the influence of the curriculum leader and the influence of teachers' professional knowledge on the implementation of the programme and on the teachers' professional development

Chapter 6 summarises all major findings and conclusions throughout the study, followed by a critical reflection on the results and the professional development framework. Finally, the general research question is answered and implications for researchers, teacher educators and policymakers are presented.

Samenvatting

Dit onderzoek is gericht op empowerment van scheikundedocenten voor onderwijs met contexten. Om docenten voor te bereiden op verandering worden tijdens onderwijsvernieuwingen meestal professionaliserings-programma's uitgevoerd. Onderzoek naar dergelijke programma's is meestal gericht op evaluatie van de opbrengsten van deze programma's zoals veranderingen in kennis en handelen van docenten, of veranderingen van leerresultaten van leerlingen. Er is meestal weinig aandacht voor het proces van professionele ontwikkeling van docenten gedurende deze programma's. Dit onderzoek heeft als doel de kennis te vergroten over de bijdrage van de activiteiten uit dergelijke programma's aan de professionele ontwikkeling van docenten. Op een meer algemeen niveau is het doel van dit onderzoek bij te dragen aan kennis over de wijze waarop professionaliseringsprogramma's voor curriculuminnovaties met contexten ontworpen en geëvalueerd kunnen worden. Om deze doelen te bereiken moet een professionaliseringsprogramma ontworpen, uitgevoerd en geëvalueerd worden. Voor het ontwerp en evaluatie van een dergelijk programma is een raamwerk nodig met daarin een beschrijving van de professionele ontwikkeling van docenten. De centrale onderzoeksvraag luidt: Waaruit bestaat een raamwerk voor het ontwerpen en evalueren van een programma voor empowerment van scheikundedocenten voor onderwijs met contexten?

Hoofdstuk 2 beschrijft de eerste stap in de synthese van het raamwerk, de identificatie van passende doelen en strategieën voor professionele ontwikkeling van docenten. Bestudering van literatuur over verschillende curriculumvernieuwingen over onderwijs met contexten en waar docenten participeren in het ontwerpen van het nieuwe curriculum, resulteerde in de volgende doelen: Docenten begrijpen het nut van contexten in scheikundeonderwijs, docenten zijn in staat om scheikundelessen met contexten te onderwijzen en te ontwerpen en docenten voelen zich zeker over hun nieuwe rol als onderwijzers en ontwerpers. Deze literatuurstudie resulteerde ook in de volgende strategieën: Onderwijzen van een eerder ontwikkelde innovatieve module, reflectie op praktijkervaringen, samenwerken met collega's en het ontwerpen van een schets van een nieuwe innovatieve module. Omdat de geselecteerde strategieën nogal algemeen van aard zijn, is hun uitwerking in verschillende professionaliseringsprogramma's onderzocht. Uit deze literatuurstudie bleek dat er geen duidelijke relaties zijn tussen de doelen, strategieën en

activiteiten van de onderzochte programma's, en dat er weinig aandacht is voor de bijdrage van activiteiten uit deze programma's aan de professionele ontwikkeling van docenten. Ook bleek dat er een specifieke volgorde van activiteiten voor het ontwerpen van onderwijsmateriaal door docenten wordt gehanteerd. Er wordt geconcludeerd dat een raamwerk een leertheorie moet bevatten die de professionele ontwikkeling van docenten beschrijft.

Hoofdstuk 3 beschrijft van de tweede stap in de synthese van het raamwerk, identificatie van een passende leertheorie voor de professionele ontwikkeling van docenten. Op grond van de doelen, strategieën en activiteiten uit hoofdstuk 2 werd Galperin's theorie voor internalisatie van mentale acties geselecteerd. Deze theorie wordt gecombineerd met de doelen en strategieën tot een raamwerk. Het raamwerk bestaat uit een onderwijsdeel en ontwerpdeel. Elke deel bestaat uit drie fasen: een oriëntatiefase, een toepassingsfase en een reflectiefase. De delen zijn gekoppeld aan elkaar, de oriëntatiefase van het ontwerpdeel bestaat in zijn geheel uit het onderwijsdeel. Ieder deel heeft zijn eigen doelen, zoals het begrijpen van en zeker voelen over het onderwijzen en ontwerpen van scheikundelessen met contexten. Met dit raamwerk kan niet alleen een programma voor empowerment van scheikundedocenten voor onderwijs met contexten ontworpen en geëvalueerd worden, maar ook kan met dit raamwerk de professionele ontwikkeling van docenten tijdens de uitvoering van het professionaliseringsprogramma onderzocht worden.

In *hoofdstuk 4* wordt het ontwerp, de uitvoering en de evaluatie van een programma dat gebaseerd is op het raamwerk beschreven. Het programma bestaat, in grote lijnen, uit het onderwijzen van een module over superabsorberende stoffen in wegwerpluiers (de context), gevolgd door het ontwerpen van een schets van een nieuwe module met een context. Essentieel is dat de contexten uit deze modules leerlingen nieuwsgierig maakt en een behoefte oproept tot het verwerven van specifieke chemische kennis ('need to know'). Zes ervaren scheikundedocenten participeerden het programma onder leiding van een programmaleider. De resultaten lieten zien dat de empowerment van scheikundedocenten voor het ontwerpen van onderwijs met contexten slechts gedeeltelijk gerealiseerd was en dat de beoogde professionele ontwikkeling in het programma slechts gedeeltelijk heeft plaatsgevonden. Op basis van de resultaten werd aanbevolen om het raamwerk en het programma op enkele punten bij te stellen en te verfijnen. Ten eerste zou de module over superabsorberende stoffen in wegwerpluiers expliciet onderwijsstrategieën moeten bevatten die het 'need to know' probleem zouden kunnen oplossen. Ten tweede zouden de docenten meer ondersteuning moeten krijgen bij het ontwerpen van een schets van een nieuwe module. Ten derde zou het raamwerk meer specifieke richtlijnen moeten bevatten om een effectief professionaliseringsprogramma te kunnen ontwerpen.

In *hoofdstuk 5* wordt beschreven op welke wijze het raamwerk is bijgesteld, hoe de nieuwe versie van het raamwerk is uitgewerkt in een nieuw programma en hoe de uitvoering en evaluatie van dit programma zijn verlopen. Het raamwerk en het programma zijn op de volgende punten aangepast. Ten eerste is de module over superabsorberende stoffen in wegwerpluiers verbeterd door een aantal onderwijsstrategieën in de module te verwerken die het 'need to know' probleem kunnen oplossen. Ten tweede is de ontwerpactiviteit aangepast door docenten een keuze te laten maken uit een aantal verschillende contextrijke inleidingen. Ten derde is het raamwerk uitgebreid met onderwijsfuncties. Deze onderwijsfuncties geven algemene beschrijvingen van mogelijke activiteiten per fase en kunnen bij het ontwerpen van het programma een brug vormen tussen de fasen uit het raamwerk en de activiteiten uit het programma. Het nieuwe programma werd uitgevoerd met een groep van zeven nieuwe scheikundedocenten en een nieuwe programmaleider. De evaluatie van het programma was gericht op de uitvoerbaarheid van de eerder genoemde aanpassingen van het programma en op de professionele ontwikkeling van docenten. Uit de resultaten bleek dat het programma leidde tot empowerment bij de docenten voor het onderwijzen en ontwerpen van scheikundeonderwijs met contexten, mits zij in een groep kunnen werken en voldoende tijd en middelen hebben. Uit de resultaten bleek ook dat de programmaleider en de professionele kennis van docenten een belangrijke invloed hebben op uitvoering van het programma en de professionele ontwikkeling van de docenten.

In *hoofdstuk 6* worden de belangrijkste resultaten van het onderzoek samengevat, gevolgd door een kritische reflectie van de resultaten en het gebruikte raamwerk. Tot slot wordt de algemene onderzoeksvraag beantwoord en worden implicaties van dit onderzoek voor onderzoekers, lerarenopleiders en de politiek beschreven.

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2000 Woudschoten Chemie Conferentie - *Waterkwaliteit*. Workshop met Hanna Westbroek (UU), 3-4 november, Zeist.

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Curriculum Vitae

Machiel Stolk werd op 29 september 1974 geboren in Dordrecht. In 1992 behaalde hij zijn Atheneumdiploma aan de OSG Walburg te Zwijndrecht en startte hij met een studie scheikunde aan de Universiteit Utrecht. Deze studie ronde hij in juni 1997 af met de specialisatie elektrochemie. Na een kortstondige verbintenis aan de Vrije Universiteit Brussel volgde hij in 1998 de cursus 'oriëntatie op het beroep van leraar' bij de vakgroep Chemiedidactiek aan de Universiteit Utrecht. In januari 1999 startte hij met de eenjarige 'in-service' opleiding tot eerstegraads docent scheikunde aan het IVLOS. Nadat hij deze opleiding succesvol had afgerond, startte hij in februari 2000, in deeltijd, als assistent in opleiding bij het Centrum voor Didactiek van Wiskunde en Natuurwetenschappen. In deze functie is het beschreven promotieonderzoek uitgevoerd.

In 2006 trad hij als docent scheikunde in dienst van 'ORS Lek en Linge' te Culemborg. Nadat hij vier jaar met veel plezier op deze school les had gegeven, startte hij in februari 2010 als lerarenopleider scheikunde aan de Christelijke Hogeschool Windesheim te Zwolle. Zijn belangrijkste werkzaamheden zijn het verzorgen van vak- en vakdidactisch onderwijs aan aankomende leraren schei- en natuurkunde en het begeleiden van studenten tijdens hun stage.

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