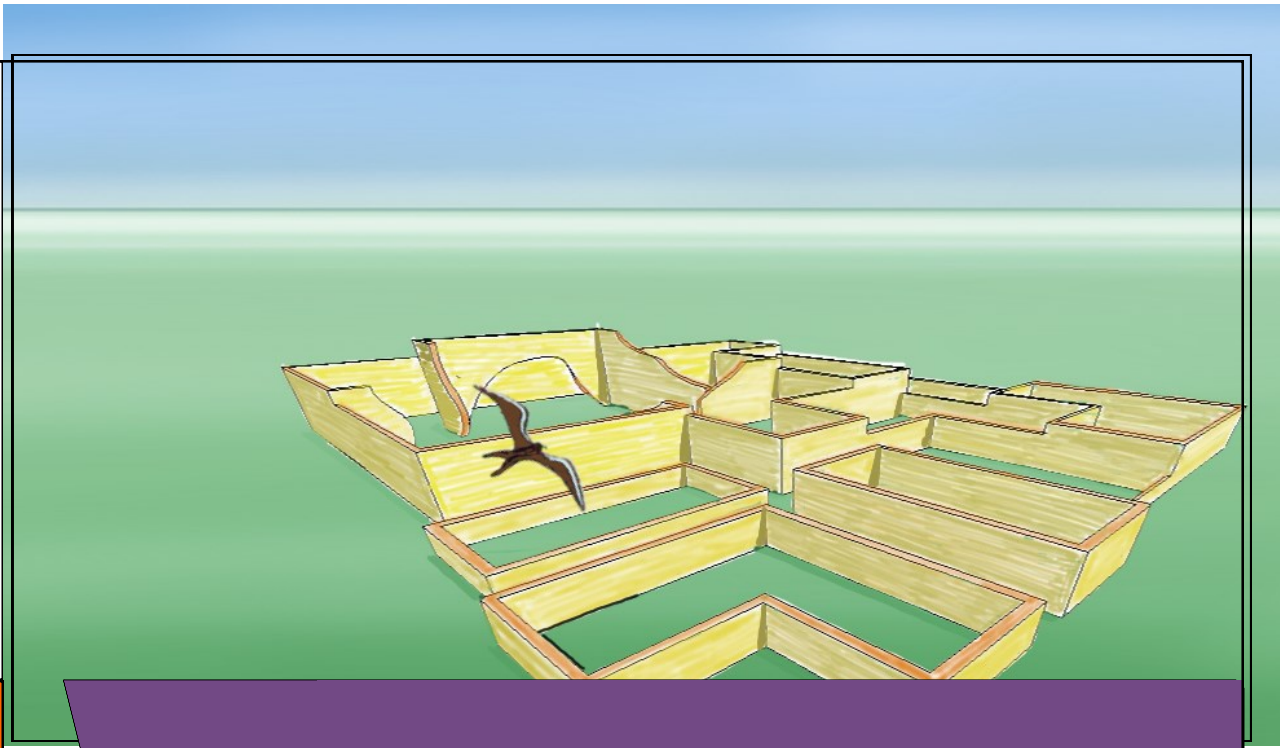

Teachers' Professional Development in Context-based Chemistry Education

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Strategies to Support Teachers in Developing Domain-specific Expertise ico

This research was carried out in the context of the Dutch Interuniversity Centre for Educational Research.

Dolfing, Ria

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Teachers' Professional Development in Context-based Chemistry Education

Strategies to Support Teachers in Developing Domain-specific Expertise

Professionele Ontwikkeling van Docenten in Context-gebaseerd Scheikunde Onderwijs

Strategieën ter Ondersteuning van Docenten in het Ontwikkelen van Domein-specifieke Expertise

(met een samenvatting in het Nederlands)

Proefschrift

ter verkrijging van de graad van doctor aan de Universiteit Utrecht op gezag van de rector magnificus, prof.dr. G.J. van der Zwaan, ingevolge het besluit van het college voor promoties in het openbaar te verdedigen op woensdag 23 oktober 2013 des middags te 4.15 uur

door

Ria Dolfing

geboren op 9 oktober 1980
te Emmen

Promotoren: Prof.dr. A. Pilot
Prof.dr. J.D. Vermunt

Co-promotor: Dr.ir. A.M.W. Bulte

Table of Contents

En de vogels ze vliegen van west naar oost Berlijn,

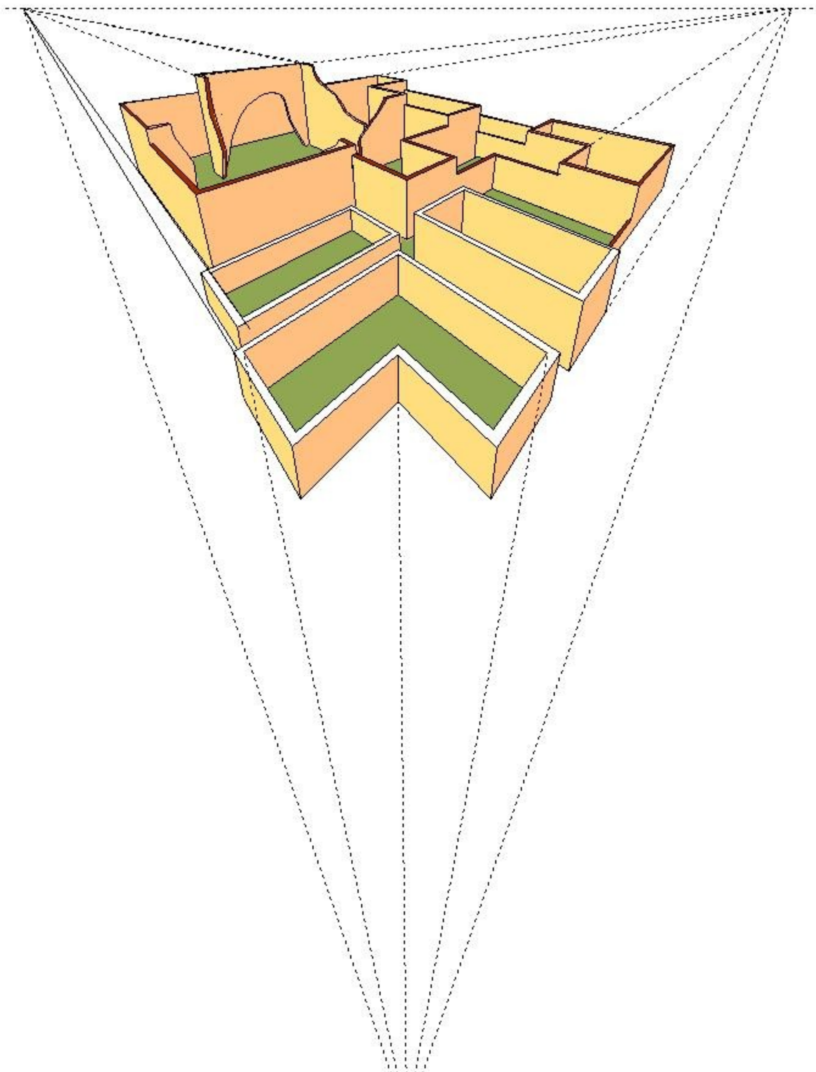
worden niet teruggefloten, ook niet neergeschoten.

Over de muur, over het IJzeren Gordijn,

Omdat ze soms in het oosten, soms ook in het westen willen zijn.

Omdat er brood ligt soms bij de Gedachtniskirche, soms op het Alexanderplein!

Uit ‘Over de muur’, Harry Jekkers



Chapter 1

Introduction and Research Overview

Introduction

Redesigning science curricula, in terms of context-based programmes, implies new domain-specific expertise that is not part of a teacher's regular expertise (Bulte, Westbroek, de Jong and Pilot, 2006; Pilot and Bulte, 2006). The successful implementation of such new curricula thus requires that teachers develop this domain-specific expertise, with respect to teaching the innovative curriculum (Van den Akker, 1999; Vos, Taconis, Jochems and Pilot, 2011).

The development of this new expertise takes place preferably in professional development programmes, in which teachers learn collaboratively (Swan, Scarbrough and Robertson, 2002). This working together in collaborative settings is reported as a promising strategy for: teacher learning and development (Butler, Lauscher, Jarvis-Selinger and Beckingham, 2004; Vescio, Ross and Adams, 2008); educational innovation (Bakkenes, Vermunt and Wubbels, 2010); school improvement (Harris and Jones, 2010); and the teaching and development of curriculum units (George and Lubben, 2002; Whitcomb, Borko and Liston, 2009). Based on these notions, there is a strong scientific interest in teachers' learning and development (Van Eekelen, Vermunt and Boshuizen, 2006; Vermunt, 2006), especially with respect to collaborative settings as a strategy to implement curriculum innovations.

Stolk et al. (2012) report on a framework for professional development, to empower teachers to implement context-based chemistry education. This framework involves phases in the professional development and functions that need to be fulfilled when teachers perform professional development activities. This framework can be used as guideline when designing professional development programmes, to support teachers in a collaborative setting, in order to develop domain-specific expertise in teaching context-based chemistry education. However, the framework does not provide specific guidelines about issues such as: how to compose the collaborative setting; how to guide discussions among teachers in the collaborative setting; how to coordinate the group dynamics among teachers; what domain-specific expertise is intended to be developed by teachers to teach context-based chemistry education; and what sequence of activities to plan within the framework, to support teachers' development of this intended domain-specific expertise. This understanding is needed to design a professional development programme to support teachers in curriculum innovations, such as context-based chemistry education. This thesis reports about a research project that was conducted to gain insight into strategies to support teachers in developing domain-specific expertise during the curriculum innovation of context-based chemistry education. In this study, these strategies concern three issues that are considered to be important for designing such a professional development programme.

The first issue involves the determination of the domain-specific expertise (Ericsson, Charness, Feltovich and Hoffman, 2006) that teachers need to teach context-based chemistry education, and the domain-specific expertise teachers develop in a collaborative setting, during a professional development programme. In contrast to most innovations in which teachers develop expertise in one new aspect, for example pedagogical approaches, the innovation of context-based chemistry education involves the simultaneous development of several new aspects of teaching new content, and implementing new pedagogical approaches. The new content involves topics in, for example, food technology, nanotechnology and biotechnology, and involves content areas such as modelling, product development and research experiments, which are not part of the conventional chemistry curriculum. The new pedagogical approaches involve collaborative learning, problem-solving procedures, research activities, and new teacher roles, to stimulate students' self-regulated learning (Henze, Van Driel and Verloop, 2007), students' feelings of ownership of their learning process (Gilbert, 2006), and meaningful chemistry education (Mortimer and Scott, 2003; Nentwig and Waddington, 2005). Consequently, implementing this innovation of context-based education involves specific and unique difficulties in teachers' professional development.

The second issue considers the collaborative setting in which teachers participate, during the professional development programme. In collaborative learning it is essential that domain-specific expertise is shared among the participants (Breu and Hemingway, 2002; Wenger, 2000). When designing the programme, decisions are made in a group composition, via the roles and tasks of the participants, and in coaching the group in discussions (Forsyth, 2010). These decisions regarding the group structure and social interaction, to support teachers to share their expertise, are important to consider in relation to teachers' development. These decisions could have a specific influence on the collaborative development of domain-specific expertise, regarding the new content and pedagogical approaches of context-based education.

The third important design issue considers the sequence of activities to plan within the programme, in order to support teachers in developing domain-specific expertise. Several general strategies are described to support teachers' development. For example, learning should be integrated in teachers' daily practice at the workplace (Bakkenes et al., 2010; Van Veen, Zwart, Meirink and Verloop, 2010); teachers need a clear motive to learn new practices (Van Eekelen et al., 2006); and the activities in the programme need to provide teachers with the opportunity to share experiences, and build upon their common knowledge base in a meaningful way (Bulte et al., 2006). It is also important that teachers should be stimulated to become involved in self-regulated learning and encouraged to gain ownership, as well as to reflect systematically on their teaching experiences in new situations

(Korthagen, 1999). However, it is unknown how these general strategies hold in curriculum innovations, when content and pedagogical approaches are both subject to change. To support teachers in curriculum innovations such as context-based education, general strategies need to be implemented productively in professional development activities, to facilitate teachers' development of domain-specific expertise.

This research project focuses on the increase of understanding of learning processes of experienced teachers in collaborative settings, as a support for the implementation of the curriculum innovation of context-based chemistry education. This research project aims to provide more understanding about how to design a professional development programme, and find strategies concerning the three design issues of the programme; composing the collaborative setting, planning activities within the framework, and determining and describing the development of the intended domain-specific expertise.

This research project is a first systemic study within a national professional development network of collaborative settings, in which teachers design and adapt curriculum materials, and develop newly shared domain-specific expertise in teaching the new curriculum (Bulte and Seller, 2011). To organize and build the network, teachers participate in a two-step programme. First, they participate in a collaborative setting to gain experience in teaching and developing context-based chemistry units, and second, they continue the programme to become coach of a teacher group, to support colleagues in teaching and developing these units. Several teachers who participate in this research project would become coaches of their own teacher group. In this way, they share their experiences with colleagues, and contribute to the implementation of the curriculum innovation.

This project aims to integrate theory and practice by implementing this curriculum innovation in a co-design (Penuel, Roschelle and Shecht, 2007) with educational designers, teachers and researchers. Therefore, the knowledge claim of this project is scientific, professional and practical in nature. The theoretical, professional and practical expertise that develops during the project is shared and published in different sources, and among different audiences involved in the curriculum innovation. This thesis describes the knowledge claim of this project in scientific publications. In addition, the coach that participates in this project shares his experience with junior coaches and in professional publications. The teachers in this project share their expertise with colleagues as ambassadors, coaches of their own group, in their own school and classes, and at educational conferences.

Theoretical perspectives of this research project

This project builds on research projects about designing teaching-learning processes in context-based chemistry education in structure-property relations (Meijer, Bulte and Pilot, 2009; Meijer, 2011). It also looks at the design of a framework for teachers' professional development in curriculum innovations (Stolk, De Jong, Bulte and Pilot, 2012). Meaningful learning in structure-property relations is problematic for students (Han and Roth, 2005). At the same time, this is a core activity in authentic contexts in chemistry (Justi and Gilbert, 2002). The project of Meijer et al. (2011) was aimed at identifying instructional principles to teach students to relate macroscopic properties to microscopic structures. The project of Stolk et al. (2012) involved an explorative study to design a framework for a professional development programme, to support chemistry teachers in teaching and designing context-based chemistry units. The theoretical background of these studies is elaborated shortly in this chapter.

The curriculum innovation of context-based chemistry education

Context-based education is considered as the learning of science content in social activities (Bulte et al., 2006; Prins, Bulte and Pilot, 2008; Westbroek, Klaassen, Bulte and Pilot, 2010). In such context-based education, students are provided with meaningful problems (Lijnse and Klaassen, 2004), for which they need to develop the intended coherent content, such that they experience their learning as relevant, and feel a sense of ownership of what is to be learnt (Nentwig and Waddington, 2005). Within such a vision, chemistry is considered as a social activity; chemical knowledge is used as a tool to execute a task, which involves solving a problem, and participants are motivated to use and develop knowledge (Meijer et al., 2009).

Based upon this vision, the designed innovative context-based unit of Meijer's project involves social activities to develop, e.g. food products, or to improve the properties of a food product in a project team. This project team, consisting of the students as team members and the teacher as a senior team member, is required to use the necessary relations between the desired properties of the food product and the structures within the product (structure-property relations), to solve the problem. Whilst addressing this problem, the team is expected to feel the need (need -to-know basis) to use and develop more knowledge about these relationships.

The main learning effect for students, in this example of an innovative context-based unit, is macro-micro thinking, using meso-levels (Meijer et al., 2009). When addressing the food problem, students start with an implicit use of macro-micro thinking, which is expanded during the project when they explain and predict the properties of the food product on macro-, meso- and micro-levels. This macro-micro thinking is made explicit to students, by letting them map their developed knowledge in a conceptual schema of structures and related properties of a material (Figure 1), and formulating the structure-property relations in ‘IF … THEN …’ sentences at the end of the project. In this conceptual schema, a material is considered as a system (macro-level), containing several subsystems (meso-levels). Depending on the specific problem in product development, relevant subsystems of structures at different meso-levels can be assigned to appropriate scales.

To address the specific context, it is necessary to ‘zoom’ into the structures within a certain product, to relate the properties of this product at a certain level to underlying structures, and to study structure-property relations on different levels of a product. The system of relevant nested structures and properties, and the explicit relations between structures and properties form the backbone of this macro-micro thinking. Depending on the type of problem (e.g. in this example, the development of gluten-free bread), a number of different meso-levels are relevant, and a certain set of explicit structure-property relations are necessary, until sufficient structures, properties and interrelations are available to address the problem at hand. Structuring of atoms and/or ions at the micro-level in a certain pattern should only be used when it is necessary to address the problem, when developing a food product with the desired properties. For teachers, teaching this content of macro-micro

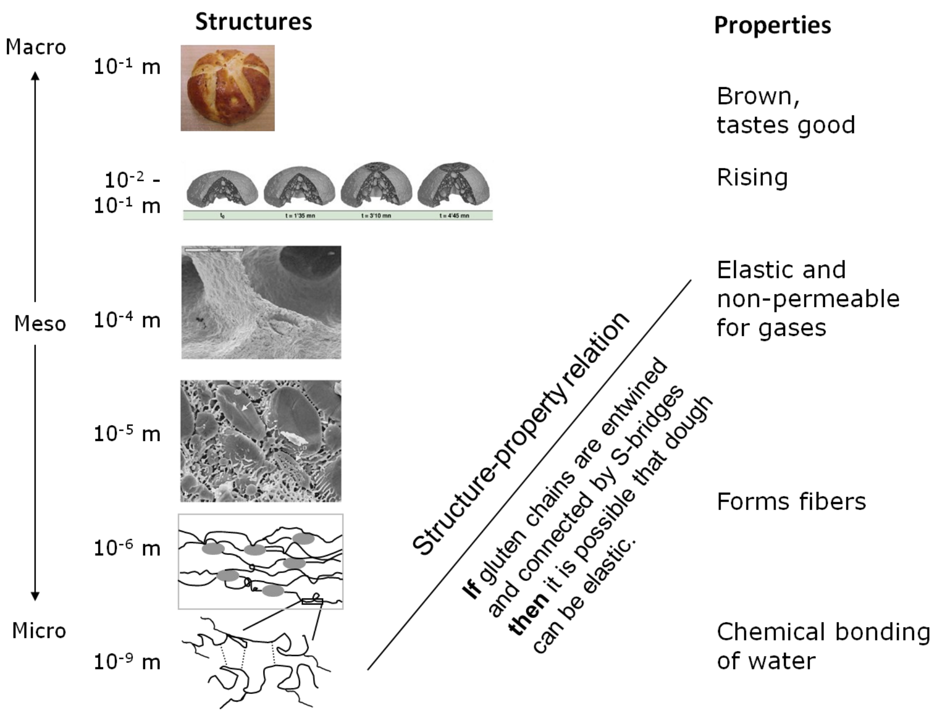


Figure 1 The conceptual schema showing explicit use of structure-property relations in wheat bread (Meijer et al. 2009)

thinking using meso-levels is new in their classroom practice, since conventional macro-micro thinking is directed towards the learning of particles, such as molecules and atoms, which are directly related to macroscopic phenomena (Taber, 2009).

The framework of teachers' professional development

For a successful implementation of context-based chemistry education, teachers are supported to develop domain-specific expertise in teaching the innovative context-based chemistry units. In the literature, several initiatives are described, in which teachers develop their expertise when they teach context-based units in collaborative settings (Butler et al., 2004; George and Lubben, 2002; Handelzalts, 2009; Voogt et al., 2011; Whitcomb et al., 2009). The strategy of collaborative learning was used to enhance teachers' beliefs that they can succeed in implementing an innovation in their own school situation (Abrami, Poulsen and Chambers, 2004).

Stolk et al. (2012) described a framework for teachers' professional development, to empower teachers to teach context-based chemistry units. Referring to Galperin's theory for the internalisation of actions (Arievitch & Haenen, 2005), the framework consists of three phases:

- Preparation phase, in which teachers prepare the unit to share initial expertise and acquire new expertise;
- Instruction phase, in which teachers instruct the unit in the teacher's own school situation, to apply and expand the new expertise;
- Reflection phase, in which teachers reflected on teaching actions and effects on students, to expand and share the new expertise.

At the beginning of the programme (initial phase), conditional functions such as 'motivating teachers to learn' and 'reveal teachers' initial expertise', need to be achieved for teachers' development. In addition, within each phase of the professional development process, functions such as 'provide teachers the opportunity to apply their domain-specific expertise in class and to reflect upon their teaching and learning experiences' need to be fulfilled by the teachers for their development to teach context-based units successfully.

The framework of Stolk et al. (2012) formed the basis of the professional development programme at the start of this research project. For the convenience of the specific research situation, the phases are renamed and the formulation of the functions are slightly adapted. However, there are no significant changes made

Phase	Function
Initial	a. Connect to teachers' views on context-based education b. Reveal 'useful' teachers' initial domain-specific expertise
Preparation	c. Let teachers discover differences and similarities among their views on context-based education and the context-based unit d. Let teachers explore strategies for teaching the context-based unit, give examples, and present conditions for use e. Provide the opportunity for teachers to define their learning goals
Instruction	f. Provide the opportunity to apply the domain-specific expertise in practice
Reflection	g. Give teachers the opportunity to reflect on their teaching and learning experiences h. Examine teachers' development by creating the opportunity for teachers to produce a product i. Evaluate teachers' development

Figure 2 The framework for professional development of teachers in teaching context-based units.

compared to the framework of Stolk et al. (2012) that could influence the results of the studies. The adapted framework is presented in Figure 2. During this research project, the framework is adapted and complemented regarding the framework itself, as well as the activities to be planned within the framework.

This research project was built upon the curriculum innovation of context-based chemistry education, as described by Meijer et al. (2009), and on the framework of teachers' professional development, as described by Stolk et al. (2012). This thesis adds to these projects by providing more understanding about which strategies in the professional development programme, based on the framework of teachers' professional development (Stolk et al., 2012), support experienced chemistry teachers in developing domain-specific expertise, specifically in teaching context-based chemistry education, based on the teaching-learning processes of Meijer et al. (2011). The central research question is provided, and methods are described shortly in this chapter. The sub questions and methods are explained in detail in the other chapters.

Research Questions

The central research question of this research project is:

What strategies, implemented in a professional development programme, support teachers in developing domain-specific expertise in teaching context-based chemistry education?

To answer the central research question, this research project involves four empirical studies. Each study contributes to understanding the learning processes of experienced teachers, in collaborative settings in curriculum innovations. The studies are related to the design issues of the domain-specific expertise teachers need and develop when teaching context-based chemistry education, the collaborative setting and sequence of activities to support teachers' development:

1. Determining the intended domain-specific expertise, to teach context-based chemistry education about macro-micro thinking in structure-property relations;
2. Describing the domain-specific expertise that teachers develop, when participating in a collaborative setting;
3. Exploring patterns in the group dynamics among participants in the collaborative setting, which influence teachers' development of domain-specific expertise;

4. Planning the sequence of activities within a framework for teachers' professional development, to support teachers' development of the intended domain-specific expertise.

Research Methods

The four studies are explorative in nature. The first study involves an exploration of new domain-specific expertise that teachers experience, who pioneer in the teaching of context-based chemistry units. To investigate the intended domain-specific expertise, a two-step phenomenological approach is used (Creswell, 2007). The two-step approach involves an exploration step of describing the new domain-specific expertise based on two teachers, who teach a context-based unit in class. In the second step, the expertise described is then verified in a broader field of teachers.

Then two case studies are conducted (Creswell, 2007) in which six and seven teachers participate, respectively, in a professional development programme, to develop domain-specific expertise to teach a context-based chemistry unit. In the first case study, the professional development programme is implemented, based on the framework for professional development (Figure 2). This case study provides data for the second and third empirical study of this research project. In the second empirical study, the domain-specific specific expertise that teachers developed during the programme is to be described. To explain this teacher development, a third empirical study is conducted on the collaborative setting in this programme. In this study, patterns in group dynamics are to be described that influence teachers' development in the collaborative setting. The second case study provides data for the fourth empirical study, about planning a sequence of activities in the professional development programme.

Data collection to explore teachers' domain-specific expertise, involves data sources in which teachers make their expertise explicit, such as interviews, mind maps, and logs, and data sources in which teachers demonstrate their expertise in their performance, such as video recordings of lessons and designed lesson material.

Data analysis follows qualitative approaches and procedures as inner-case analyses (Miles and Huberman, 1994) and categorical aggregation (Stake, 1995). In the first empirical study, the categories of teachers' domain-specific expertise to teach context-based chemistry education are to be explored. These categories are used in the two case studies, to analyse teachers' domain-specific expertise during the professional development programme. Results are to be presented within these categories. The four studies with the specific research questions are described below and schematically in Figure 3.

Outline of the thesis

The research activities of this thesis are described in four chapters. Here, the outline of the thesis is elaborated.

Chapter 2

Chapter 2 presents an explorative study to determine the new domain-specific expertise that teachers need to teach context-based chemistry units. In this study, teachers pioneer in the curriculum innovation and teach the context-based chemistry units. Based on what these teachers experience, the new additional domain-specific expertise is determined and described. This chapter provides an answer to the following research question:

What new domain-specific expertise do experienced chemistry teachers need to acquire in order to teach an innovative context-based unit about macro-micro thinking, using meso-levels in structure-property relations?

Chapter 3

Chapter 3 focuses on the development of the intended domain-specific expertise when teachers participate in a professional development programme, based on the framework presented in Figure 2. The study involved a case study approach, in which teachers, guided by a coach, participate in a collaborative setting to teach a context-based chemistry unit. This case study provides an answer to the following research question:

What domain-specific expertise do teachers develop when they teach a context-based chemistry unit about macro–micro thinking in structure–property relations in a collaborative setting?

Chapter 4

Chapter 4 focuses on explaining teachers' development of domain-specific expertise, from the perspective of group dynamics in the collaborative setting, as described in Chapter 3. This study aims at identifying patterns in group dynamics that influence the development of domain-specific expertise, when teachers participate in a collaborative setting. This study provides more insight into why and how collaboration enhances teacher learning, and how to improve professional development programmes, to support teachers in teaching context-based chemistry units, and develop the intended domain-specific expertise. This study provides an answer to the following research question:

What patterns in the group dynamics of collaborating teachers can be identified that influence teachers' development of the domain-specific expertise that is required for teaching a context-based unit?

Chapter 5

The scope of the study described in Chapter 5 involves evaluating a professional development programme in the light of teachers' sense-making processes, as described in the model of Luttenberg et al. (2011), in the new aspects of teaching context-based chemistry education. To develop domain-specific expertise, teachers need to accommodate their frame of teaching the conventional curriculum towards teaching of the new curriculum. Based on the results described in Chapter 3, this study focuses especially on planning a sequence of activities within an adapted framework of teachers' professional development, to support teachers in conducting a problem analysis for teaching the new content of macro-micro thinking in structure -property relations. This provides a more general understanding about strategies for teachers' professional development in curriculum innovations. In this study, the research question is formulated as:

To what extent does the sense-making process during the professional development programme, based on the adapted framework, result in teachers' accommodation of
-the specific context-setting in class,
-the performance of the new teacher's role, and especially
-teaching of the new content in context-based chemistry education?

Chapter 6

Chapter 6 summarizes the main conclusions of this research project, regarding the strategies found that could be implemented in a professional development programme. The knowledge claim concerning the design issues of the collaborative setting, the framework and activities, and the required and development of domain-specific expertise, are discussed in a broader perspective. In addition, implications of the conclusions are provided for designing professional development programmes.

Figure 3 Overview of the research project

→

Chapter 1 Design issues	The collaborative setting	The sequence of activities within the framework	The development of intended domain-specific expertise
Explorative study			**Chapter 2** Determining the intended domain-specific expertise
First case study	**Chapter 4** Exploring patterns in group dynamics that influence teachers' development of domain-specific expertise		**Chapter 3** Describing the domain-specific expertise that teachers develop during the programme
Second case study		**Chapter 5** Planning a sequence of activities within the framework to support teachers' development	
Chapter 6 Understandings for designing	Strategies in composing and coordinating collaborative settings to support teachers' development	Strategies in planning the activities to support teachers' development	Description of the intended domain-specific expertise

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Chapter 1 Design issues	The collaborative setting	The sequence of activities within the framework	The development of intended domain-specific expertise
Explorative study			**Chapter 2** Determining the intended domain-specific expertise
First case study	**Chapter 4** Exploring patterns in group dynamics that influence teachers' development of domain-specific expertise		**Chapter 3** Describing the domain-specific expertise that teachers develop during the programme
Second case study		**Chapter 5** Planning a sequence of activities within the framework to support teachers' development	
Chapter 6 Understandings for designing	Strategies in composing and coordinating collaborative settings to support teachers' development	Strategies in planning the activities to support teachers' development	Description of the intended domain-specific expertise

Chapter 2

Domain-specific Expertise of Chemistry Teachers on Context-based Education About Macro–Micro Thinking in Structure–Property Relations[1]

Abstract

This study aims to determine and describe the new domain-specific expertise of experienced chemistry teachers in teaching an innovative context-based unit about macro–micro thinking in structure–property relations. The construct of 'teachers' domain-specific expertise' was used to analyse the new repertoire chemistry teachers need to acquire to teach a context-based unit and achieve the intended effects of the curriculum innovation. A phenomenological approach of exploration and verification of teachers' new repertoire resulted in the description of seven themes. These themes were related to the new aspects of the unit: the context-setting, the teacher's role and the new content. In addition, the results show that the theoretical framework of teachers' domain-specific expertise is feasible for the analysis and description of their new repertoire in the domain of teaching a context-based unit. Further research is necessary to explore the use of the framework from the perspective of teachers' professional development, where affective components in teachers' learning processes play an important role.

[1] This chapter is published as:

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Introduction

Redesigning science curricula, especially when context-based units are included, implies new domain-specific expertise that is not part of teachers' existing domain-specific expertise. A context-based science curriculum implies a new role for teachers in relation to their students and new content is situated in a context setting. This involves new domain-specific expertise, additional to the existing conventional expertise of experienced teachers, and alters teaching in line with the new science curriculum. To implement such a curriculum innovation successfully, adequate professional development is necessary in which teachers acquire new domain-specific expertise to be able to achieve the intended effects (Tynjälä, 2008; Van Driel, 2006).

A programme for professional development should be based on understanding how teachers acquire new domain-specific expertise effectively to teach context-based units successfully. Teachers are professionals, learning and developing their expertise by performing activities in their domain of practice. One of the conditions for designing such a professional development programme is that this expertise is carefully described. Therefore, a theoretical framework is needed to describe what this expertise actually is when innovative context-based units are taught.

This study focuses on describing the new domain-specific expertise, which teachers need to acquire to teach innovative context-based chemistry units in which the context-setting determines an important part of the content of macro-micro thinking in structure-property relations and the pedagogical approach including a new teacher's role in class (Meijer, Bulte and Pilot, 2009). This detailed information on how and what should be planned is a necessary first step before professional development programmes for teachers can be designed.

Describing teachers' development of domain-specific expertise

The theoretical framework draws upon two perspectives: (1) a construct to describe teachers' domain-specific expertise; and (2) an analysis of the new aspects of the context-based unit: (i) the context setting, (ii) the teacher's new role, (iii) the new content.

Teachers' domain-specific expertise

Domain-specific expertise is mostly described within the construct of pedagogical content knowledge (PCK) (Shulman, 1986; Shulman, 1987). With respect to context-based chemistry units, however, the construct of PCK could be confusing. In PCK, the focus is on the relation between specific content knowledge and pedagogical knowledge (Lee and Luft, 2008). 'Context' within the construct of PCK is often defined as the school situation in which the teacher teaches. This makes it necessary to use a different construct where 'context' has a different meaning, as in 'context-based education'. 'Context' in context-based education is conceived as a setting within which the student's behaviour and mental experiences are situated, using the relationship of extra-situated background knowledge and specific language (Gilbert, 2006). In addition the 'context' must provide the basis for developing coherent 'mental maps' of the content so that students experience learning chemistry as relevant and they feel a sense of ownership of what is to be learnt. In this study, the focus on teachers' acquisition of new domain-specific expertise depends on (i) the situated setting when a context-based unit is taught with (ii) a specific role of the teacher to let students feel the relevance of learning chemistry and ownership of what they learn and with a specific (iii) content organised in coherent 'mental maps'. Consequently, the new domain-specific expertise teachers need to acquire is not only related to content knowledge and pedagogical knowledge, but also to the context setting. This implies the acquisition of integrated new domain-specific expertise across all aspects of teaching a context-based unit. Therefore, a theoretical framework is needed in which the new domain-specific expertise can be described holistically, acknowledging the interrelation of (i) the context setting, (ii) the teacher's role and (iii) the new domain-specific content.

Based on the studies of Sternberg (Cianciolo, Matthew, Sternberg and Wagner, 2006; Ericsson, Charness, Feltovich and Hoffman, 2006; Tynjälä, 1999), expertise is defined as 'the ability to perform successfully'. An expert can be considered as a multi-dimensional prototype representing a central or 'prototypical' category member, with a summary of common expertise that is characteristic of a specific domain (Ropo, 2004). A similar definition of this 'common' expertise for one specific category of experts can be found in the 'common' part of teacher knowledge related to a specific domain (Verloop, Van Driel and Meijer, 2001). This common part of knowledge represents knowledge shared by a certain group of teachers performing within a specific domain; for example, teaching a particular curriculum to a particular category of student. It involves explaining certain kinds of content or performing certain teachers' roles to this specific category of students. This knowledge is mostly acquired by experience. Based on the definition of Stenberg, new domain-specific expertise of a 'prototypical' teacher in this study could be described in themes formulated as abilities to perform successfully in the domain of teaching a context-based chemistry unit. In this, 'successfully' is defined as teaching the unit in such a way that according to the teacher, the intended effects of the curriculum innovation are achieved.

The expertise of such a prototypical teacher is described by seven general characteristics (Tynjälä, 1999). These characteristics of expertise should be considered as a holistic framework (Smith and Strahan, 2004). Therefore, the interrelationships between the characteristics of expertise can be considered as shown in Figure 1. An expert teacher is characterised by their use of advanced problem-solving processes (1) when teaching context-based units and achieving the intended effects. The use of advanced problem-solving processes in the teacher's specific domain of practice requires a large repertoire of declarative and procedural knowledge (2). In addition, it requires advanced knowledge organisation (3) for the teacher to know what intended effects he/she has to achieve (effect), how he/she has to achieve the intended effects (actions) and when and where he/she has to act to achieve the intended effects (situations) (Dunphy and Williamson, 2004; Sternberg, 1999). The teacher's advanced problem-solving processes (1) lead to successful performance in class, when the teacher has the practical ability (7) to execute the (routine) actions (6). Since teachers' knowledge is mostly acquired by experience, an expert teacher is characterised by using his/ her repertoire effectively (4) and expanding his/her repertoire as a result of acting in domain-specific situations (5) when teaching context-based units in class.

Teachers' expertise is deeply embedded within teaching practice. The description of new domain-specific expertise is strongly related to teaching a context-based unit. This study focuses on describing the new repertoire (2&3) teachers need to acquire and show in practical ability (7) and (routine) actions (6) in class, when teaching a context-based unit and achieving the intended effects. The themes in the new

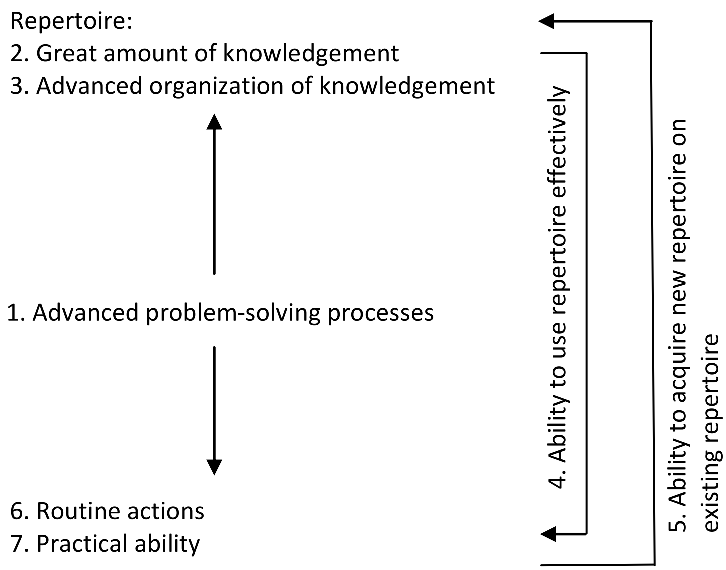

Figure 1 Interrelationship of the characteristics of expertise

repertoire are formulated as abilities and are described in terms of Dunphy & Williamson’s (2004) dimensions effect, actions and situations. The described abilities need to be part of the teacher’s repertoire to teach a context-based unit and achieve the intended effects.

Expertise recognises the diversity of abilities that is the basis for a successful performance using repertoire effectively to teach context-based units, involving (i) the context-setting, (ii) a specific teacher’s role and (iii) the new content. Ericsson argued that expertise exists in degrees rather than in an all-or-nothing fashion (Ericsson et al., 2006). Expertise includes domain-general information-processing capabilities which recognise differences between domains. One could reasonably say that an expert brings a richer repertoire to problem situations than novices in certain domains of practice and, as a result, has the ability to solve such problems more effectively. Experts are faster and more efficient in their problem-solving and seem to arrive at new and appropriate solutions to problems within their domain. Experts in the same domain can be different from each other by having different repertoires, although all are categorised as experts (Ropo, 2004; Smith and Strahan, 2004), so expert teachers all teach the same context-based units, and can show different actions to achieve students’ intended learning effects.

Within curriculum innovation aimed at a context-based curriculum neither teachers nor curriculum designers and researchers are full experts in the domain of teaching these innovative context-based units, since they are still under development. What new domain-specific expertise teachers need to acquire to teach these units and achieve the intended effects must finally be determined by teaching these units in class followed by evaluation and reflection on this teaching together with the designers. When teachers prepare and execute a unit and reflect on teaching this unit, events can be described in which teachers make explicit or show what effects they tried to achieve and what actions they took in what situations to achieve these effects. To describe the new domain-specific expertise, events describing the teacher’s actual actions in specific situations to achieve certain student effects can be interpreted and categorised in themes in teachers’ repertoire, as described in the previous paragraph. Such described events could give more insight into the preferred intended events: that is, intended effects and preferred actions in specific situations that are intended by the designers of the curriculum innovation. Similarities and discrepancies between the described events and the preferred events could provide more insight into the actual teacher’s repertoire, as well as the additional repertoire teachers need to acquire.

Analysis of the new aspects of innovative context-based units

Within the international trend towards innovations in science education (Pilot and Bulte, 2006), this study considers context-based education as the learning of science content in social activities (Bulte, Westbroek, de Jong and Pilot, 2006; Prins, Bulte and Pilot, 2008; Westbroek, Klaassen, Bulte and Pilot, 2010). In such context-based education students are provided with meaningful problems (Lijnse and Klaassen, 2004) for which they need to develop the intended coherent content, such that they experience their learning as relevant and they feel a sense of ownership of what is to be learnt. Within such a vision, chemistry is considered as a social activity; chemical knowledge is used as a tool to execute a task, which involves solving a problem, and participants are motivated to use and develop knowledge (Meijer et al., 2009). Based upon this vision, the designed innovative context-based unit involves social activities to develop food products or to improve the properties of a food product in a project team. This project team, consisting of the students as project members and the teacher as a senior member, is required to use the necessary relations between the desired properties of the food product and the structures within the product

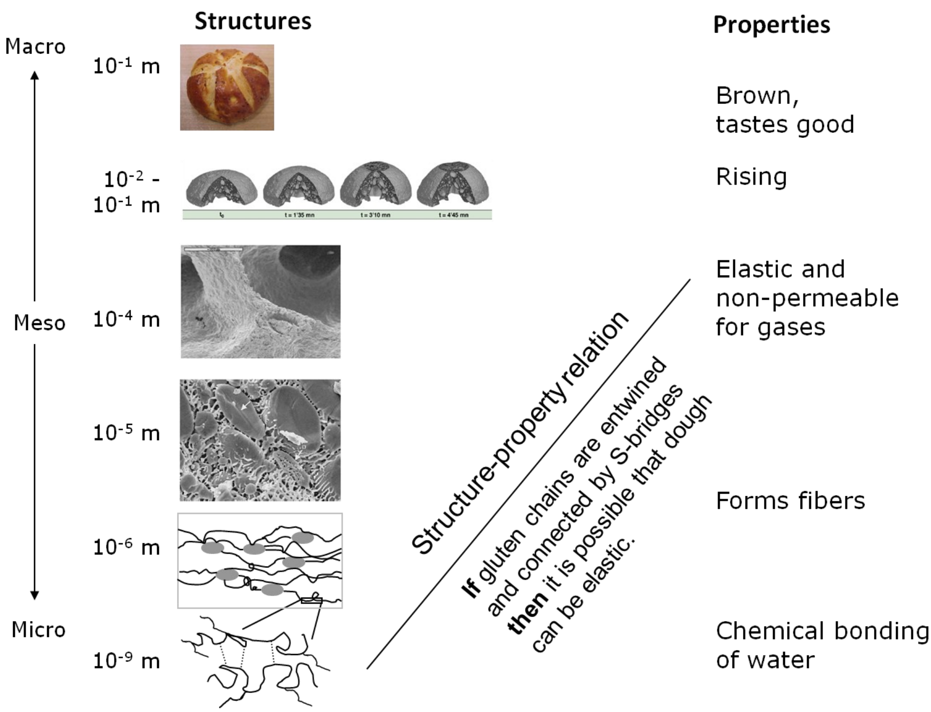

Figure 2 The conceptual schema showing explicit use of structure-property relations in wheat bread (Meijer et al. 2009)

(structure-property relations) to solve the problem. Whilst addressing this problem, the team is expected to feel the need (need-to-know basis) to use and develop more knowledge about these relations. An example of such a unit is given in the Appendix.

The main learning effect for students in this example of an innovative context-based unit is macro-micro thinking using meso-levels (Meijer et al., 2009). When addressing the food problem, students start with an implicit use of macro-micro thinking which is expanded during the project when they explain and predict the properties of the food product on macro-, meso- and micro-levels. This macro-micro thinking is made explicit to students by letting them map their developed knowledge in a conceptual schema (Figure 2) of structures and related properties of a material, and formulating the structure-property relations in 'IF ..., THEN ...' sentences at the end of the project. In this conceptual schema, a material is considered as a system (macro-level) containing several subsystems (meso-levels). Relevant structures at different meso-levels can be assigned to appropriate scales.

To address the specific context, it is necessary to 'zoom' into the structures within a certain product to relate the properties of this product at a certain level to underlying structures, and to study structure-property relations on different levels of a product. In Figure 2, the exemplary product is wheat bread. The system of relevant nested structures and properties and the explicit relations between structures and properties form the backbone of this macro-micro thinking. Depending on the type of problem (e.g. in this example, the development of gluten-free bread), a number of different meso-levels are relevant and a certain set of explicit structure-property

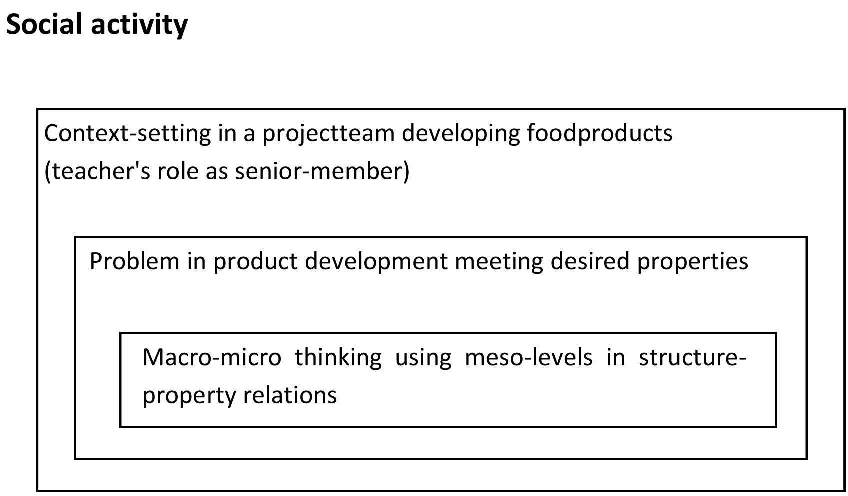

Figure 3 Overview of a context-based chemistry unit about macro-micro thinking in structure-property relations

relations are necessary until sufficient structures, properties and interrelations are available to address the problem at hand. Structuring of atoms and/or ions at the micro-level in a certain pattern should only be used when it is necessary to address the problem when developing a food product with the desired properties. For teachers, teaching this content of macro-micro thinking using meso-levels is new in their classroom practice, since conventional macro-micro thinking is directed towards the learning of particles such as molecules and atoms, which are directly related to macroscopic phenomena (Taber, 2009).

Following the specific context-setting and the content of macro-micro thinking, the teachers are expected to adopt a role as senior members of the project team (Henze, Van Driel and Verloop, 2007) to stimulate students' self-regulated learning and to encourage a feeling of ownership when addressing the problem to develop a food product. The role of the teacher involves managing and guiding the team of students as they carry out the product development procedures. A teacher, acting as a supervisor, guides their team and monitors the students' learning process in a different way from the conventional evaluation of correct or incorrect answers (Mortimer and Scott, 2003). The teacher's role is more of an experienced participant of social activity who is expected to be more competent in using conceptual knowledge and macro-micro thinking. Furthermore, they are expected to educate students to participate meaningfully in such social activity.

In summary, in contrast to typical conventional teaching, the teaching of such a context-based unit involves new domain-specific expertise for teachers in terms of: (i) the setting of the context in class with a project team tasked with a problem in product development; (ii) the new teacher's role as the senior, more experienced, project team member; and (iii) the content of macro-micro thinking in structure-property relations and intermediate 'meso' levels. The context chosen determines the nature of the content of macro-micro thinking and the teacher's role as senior member of the project team. Figure 3 gives an overview of the relations between (i) the context-setting, (ii) the teacher's role and (iii) the content in the designed innovative context-based unit about macro-micro thinking using meso-levels in structure-property relations.

Research Question

Using the theoretical framework of the construct of domain-specific expertise in relation to the domain of teaching innovative context-based units, including (i) the context-setting of working in a project team developing a food product, (ii) the teacher's role as senior member of a project team, and (iii) the content of macro-micro thinking in structure-property relations, we pose the following research question:

What new domain-specific expertise do experienced chemistry teachers need to acquire in order to teach an innovative context-based unit about macro-micro thinking, using meso-levels in structure-property relations?

Method

To investigate what kind of new domain-specific expertise a teacher needs in order to teach innovative context-based units we use a two-step phenomenological approach (Creswell, 2007). In the first step, the expertise is explored, based on two case studies, A and B. In the second step, the explored expertise is extended and verified in a broader field, by interviewing teachers who teach similar context-based chemistry units.

Step One: Exploration of expertise

There is an international trend to implement context-based curricula (Pilot and Bulte, 2006), which are being developed in secondary schools in the Netherlands. In this respect, case study A is based on the teaching of a context-based chemistry unit by two teachers in a Dutch upper-secondary class in their own school situation. This case study included the preparation of both teachers to teach a particular unit, the execution of this unit in class and the evaluation and reflection of this execution.

The preparation consisted of a discussion between the two teachers and the designer of the unit. In addition, the teachers carried out some of the practical activities from the unit. The designer of the unit discussed (i) its context-setting, (ii) the teacher's role and (ii) its content with the teachers, concentrating on the teachers' understanding of the intended effects to be achieved by teaching the unit. This preparation consisted of two meetings. Since the unit was taught by two teachers, they had to have intermediate meetings to fine-tune their lessons.

During the evaluation and reflection, the designer, together with the teachers, evaluated the effects set for the students during preparation and the difficulties the teachers might face in teaching the unit. The whole teaching of the unit took three weeks during regular lessons at school. In total, this unit included 20 lessons, each consisting of 50 minutes of class teaching time. Because of the explorative character of this study, this took longer than would have been necessary if only one teacher had taught the unit or if the teachers had been more experienced in teaching context -based units.

During the project the teachers were observed and interviewed by the researcher (author of this thesis) as a participant observer (Creswell, 2007), to gather data to find out what kind of new domain-specific expertise they used compared with their conventional teaching. In the interviews, the teachers and investigators recalled events about the intended effects of each lesson, the extent to which the effects were or were not achieved, what actions they executed differently compared with their conventional teaching, and what they intended to change in the next lesson. These events were clustered and analysed, resulting in the description of the repertoire under possible themes (an intermediate stage between events and themes) needed to teach innovative context-based units (this analytical procedure will be explained in detail in 'Analysis and Findings'). These possible themes were formulated as new abilities required apart from those of the teachers' conventional teaching. They were related to (i) the context-setting, (ii) the teacher's role and (iii) the content of a context-based unit (Figure 4).

Case study B was the implementation of the same context-based unit as in case study A in a laboratory situation taught by one teacher, who was part of the research team. In this case study the project took a full week, during a specially designed project week. At the end of each day, the teacher and the designer of the unit reflected on experiences and discussed the anticipated progress. In addition, they reflected on the whole project week after it was finished. The teacher's observed actions and arguments about the intended effects of her actions were described in events. These events were added to the emergent possible themes of case study A. The possible themes for acquiring a new domain-specific expertise were then adapted and condensed into themes and theme descriptions including effects, actions and situations.

To validate the results of the two case studies, two strategies were used (Creswell, 2007): 'member check' and 'peer review'. The teacher of case study B watched video fragments of her own teaching while judging her own actions (member check). Then she was interviewed about her interpretations of what happened during the teaching in those fragments and the appropriate actions used to achieve the intended effects. In addition, she was interviewed about the actions that could be used in these fragments when the intended effects were apparently lacking and alternative actions had to be applied. These interpretations were linked to the descriptions of the themes and the descriptions were adapted or expanded when necessary. The peer review of the video fragments gave a critical analysis of methods, meanings and interpretations and was carried out by the third author of this paper.

Step Two: Verification of expertise

The themes that emerged from the two case studies were verified in a phenomenological research design (Creswell, 2007). Therefore, five Dutch upper-secondary class teachers in the field were interviewed. In semi-structured interviews the experiences of these teachers of similar context-based units were used to verify and further specify the themes. Therefore, a semi-structured interview scheme was constructed using the themes and theme descriptions emerging from the case studies as topics. First, teachers were asked to talk about their experiences in teaching the context-based units. Meanwhile, the researcher asked questions to clarify the issues. Second, when teachers did not mention any events in a specific topic, the researcher asked the teacher specifically to talk about experiences of that specific topic. During the interviews, the questions focused on finding additional information to determine themes, adjust the dimensions of themes and enrich the theme descriptions.

After analysis of the interviews, the resulting themes and theme descriptions were validated through another 'peer review' (Creswell, 2007). The peer reviewer had no connection with this study. She examined whether or not the theme descriptions were supported by selected fragments from the interviews. In addition, in discussion, the theme descriptions were adapted in consensus, reformulated if they needed to be more specific and expanded as necessary.

Participants

The two teachers in case study A had 36 and seven years of experience. These teachers were acquainted with context-based education and the design of the context-based unit. That is, they were more informed and experienced compared with their colleagues in the field. The designer of the context-based unit was a chemistry teacher with ten years' experience in secondary education who was carrying out a PhD project for three years on design-based research on a context-based unit. The researcher was a PhD student with two years of teaching experience in secondary education.

The teacher of case study B had five years' experience in secondary education and seven years' in academic classes, and was involved in designing the units. Therefore she was acquainted with the theoretical background of the design and the intended effects of the unit.

The students in both case studies were aged between seventeen and nineteen years old. They were in the upper-secondary class of pre-university education and had not participated in context-based education before.

The interviewed teachers were Dutch upper-secondary class chemistry teachers involved in an educational programme of teachers exploring the use of innovative context-based chemistry units in their lessons (Nieuwe-Scheikunde, 2010). They had one year's experience in teaching innovative context-based chemistry units designed on the same principles described in Figure 3.

Materials

The unit used in case study A and B involved a project team developing a gluten-free food product using corn bread as an example. The students had gradually to (re) construct a conceptual scheme (Figure 2) for the development of gluten-free bread during their problem-solving procedures, and then generalise it for gluten-free food products using structure-property relations and macro-micro thinking with intermediate 'meso' levels as key elements. A more detailed description of the outline of the unit including the problem description and activities that students executed can be found in the Appendix.

The two units carried out in the educational programme and taught by the interviewed teachers for verification of the description of new domain-specific expertise are based on the same principles (Figure 3) as the unit used in the two case studies, A and B. Two units about macro-micro thinking in 'unbreakable' ceramic beakers and 'improved' absorption material for nappies were addressed by the students (Meijer et al., 2009).

Data collection

In case study A, the field notes of the author of this chapter, who participated as a participant observer (Creswell, 2007), were used to guide the data collection in the teacher's , actions and assessment of their practical abilities (characteristics 2&3 and 6&7, Figure 1). During the observations and discussions, special attention was paid to the abilities of the teachers to (i) set the context within the classroom when a project team was working on food products, (ii) perform the teacher's role as a senior member of the project team and (iii) teach the content of macro-micro thinking in structure-property relations (Figure 3). Video/voice recordings were collected for all preparation meetings and lessons on the execution and evaluation of/reflection on teaching the innovative context-based unit. In addition, the teachers filled in reflection forms (characteristics 2&3, Figure 1) after every lesson to recall events. During case study B, all lessons were video- and audio-taped (characteristics 6&7, Figure 1). The semi-structured interviews were audio-taped and the interviewer (author of this thesis) collected field notes.

Analysis and Findings

Data analysis and findings are presented separately for the exploration of new domain-specific expertise and the verification of this expertise. The analysis resulted in the description of seven themes (a-g, Table 1), regarding teachers' new domain-specific expertise needed to teach innovative context-based chemistry units about macro-micro thinking in structure-property relations. The seven themes are described in the dimensions: effect, actions and situations. As an example, the analysis of one theme (theme g, Table 1) is used to illustrate how the analysis resulted in the determination and description of all themes.

Exploration of expertise: finding and describing themes

The aim of the analysis was to determine the themes in the repertoire of experienced chemistry teachers when teaching a context-based unit about macro-micro thinking in structure-property relations (see the interrelationship of the characteristics in expertise, Figure 1). It was decided that field notes taken during lessons and meetings in case study A should be used as a primary data source, because these data gave the best insight into the teachers' repertoire in terms of the intended effects, actions and situations when teaching the unit and how the teachers actually acted in class beyond their conventional repertoire. A first exploration of possible themes in their repertoire resulted from the interpretation of data about the teachers' actual actions and abilities and their understanding of the intended effects of the innovative context-based chemistry unit about developing a gluten-free corn bread.

First, relevant fragments of field notes were selected. Criteria for fragments were that they contained (parts of) events: teacher's actions and/or achieved effects on students in situations related to (i) setting the specific context, (ii) performing the teacher's role as a senior project team member and/or (iii) teaching the new content of macro-micro thinking. The fragments were labelled, categorised and summarised as events in relation to the research question. The description of events gave an insight into which possible themes in the teachers' new repertoire could be determined that were not part of the teachers' existing repertoire. Fragments were labelled, categorised and summarised in four categories of events:

1. When preparing for the unit, the teachers linked their knowledge about gluten to their existing knowledge about proteins (which they addressed in micro-level terms). In addition, they expected that the students would need the same knowledge about proteins in order to achieve the effect of developing knowledge about gluten. Therefore, they taught a chapter of a general chemistry textbook about proteins before they taught the unit about developing a gluten-free corn bread, to ensure that the students knew enough about proteins.

2. During execution of the unit teachers often related properties on macro-level to structures on micro-level without explicitly including relevant meso-levels.
3. During the execution of the unit, the teachers focused on macro-level and practical procedures. The instructions to students about how to improve gluten-free corn bread required a trial-and-error procedure, rather than an argued procedure on how to develop a food product when improving the gluten-free corn bread.
4. It was difficult for the students to understand on what level (macro-, meso-, micro-) they were reasoning, thinking or arguing about the improvement of the gluten-free bread. The teachers used implicit terminology to point out properties on a certain level. They used explicit terminology for properties at a macro-level when referring to properties on a meso-level, and vice versa. In addition, the teachers used the terms 'structure' and 'property' without giving or negotiating a clear definition. Sometimes they used the term 'property' when they referred to 'structure', and vice versa.

These four core events indicate that teaching macro-micro thinking using meso-levels in structure-property relations in class was not part of the teachers' existing repertoire. Teachers needed to acquire this repertoire to have the practical ability to teach the content of this macro-micro thinking. To facilitate chemistry teachers to acquire the new domain-specific expertise when teaching macro-micro thinking in structure-property relations, a professional development programme requires activities which expand the teachers' repertoire with respect to this new content. Based on this analysis, a possible theme explaining one of the requirements for teachers at this point was formulated as follows:

'*Suitable knowledge about macro-micro thinking using meso-levels for describing structure-property relations'.*

The possible themes were further specified and refined into themes and theme descriptions using data from case study B. The themes gave more insight into what new domain-specific expertise is needed to expand teachers' repertoire for teaching the context-based units about macro-micro thinking in structure-property relations. Video recordings of case study B were analysed in chronological order. During the analysis of the video data, events related to the possible themes determined in the analysis of case study A were selected. Subsequently, the themes were summarised and reorganised into the following dimensions: effect (what to achieve); actions (how to achieve); situations (when/where to achieve).

The four described events and other events were described and categorised within the possible theme mentioned above about macro-micro thinking; such events comprised, for example (case study B):

1. During a plenary discussion (Activity 6, Appendix) of the project team, the teacher attempted to stimulate the students ideas for improving the properties of gluten-free bread by considering a deeper structure within the structure of bread (meso-level, Figure 2). In a question-and-answer interplay, she expected certain answers. As a result, this interaction of short answers and questions made the students guess the 'right' answers instead of really relating properties on a macro-level to structures in a meso-level.
2. In a plenary discussion about the choice of additives to replace the gluten in bread for the improvement of the properties of corn bread (Activity 8, Appendix), instead of the teacher linking properties at macro-level to structures at meso-levels, it ended in a discussion about what percentage of the additives should be used in the recipe for baking bread. None of the students made the connection between structures and properties; nor did the teacher make the connection explicitly. She focused on arguments about why certain compositions were chosen. As a result, for the students, the baking of the bread with the desired properties became a trial-and-error procedure.
3. During plenary discussion (Activity 10, Appendix), the teacher tried to get students to scale structures at meso-level and link to the properties at macro-level. The teacher reasoned directly from macro-level to micro-level, instead of bridging the gap between macro-level and micro-level by using meso-levels explicitly.
4. During discussion (Activity 14, Appendix), students did not explicitly apply macro-micro thinking by using meso-levels when reasoning about the project. The discussion only included macro-properties and micro-structures. The teacher did not lead the discussion in the intended direction nor structure the decisions made.

Although the teacher in case study B was more acquainted with the theoretical background of macro-micro thinking in structure-property relations, knowledge about teaching this new content in class was not part of her existing repertoire. Chemistry teachers need to acquire the new domain-specific expertise to be able to teach macro-micro thinking in structure-property relations to students. This expertise involves not only suitable knowledge about macro-micro thinking in structure-property relations, but it also requires knowledge about teaching this new content to students as well. Based on these events, the possible theme mentioned above could lead into the theme with a better explanation of what it is about (see above p.20) and formulated as:

'Advanced ability in teaching macro-micro thinking using meso-levels to explain and predict structure-property relations'.

This theme can be described in dimensions. The 'effect' in students that the teacher intended to achieve, when teaching the innovative context-based unit, is that students gain the ability to relate properties of a material at a certain level in the conceptual scheme (Figure 2) to the underlying structures. Therefore, expertise is needed to facilitate teachers in order to anticipate students' comments and to give them feedback. For example, the 'actions' the teacher could take in class are indicating and communicating constantly about what macro-, meso- or micro-level the project team are referring to at several stages of the project work, and guiding students in their formulation of structure-property relations like 'IF a product has structure X, THEN the product has property Y'. Through the teacher exercising a greater awareness of language use, students may gain more insight into the relevant meso-levels that the teacher and the students refer to during the project work. This analysis eventually led to the specific description of this theme, summarised in Table 1 as 'theme g'.

Additional analysis of the recordings and field notes from the intermediate meetings showed that the teachers of case study A were very insecure about their teaching and did not have much expectation that students would achieve their learning effects. They showed reluctance in organising student-centred instruction and in allowing the students to work independently, since they reported a lack of trust in the students' ability to work in a self-directed way. In addition, they showed scepticism about the curriculum innovation before they taught the unit (the preparation meetings).

The teacher in case study B also experienced difficulties. In the introduction of the unit to the students, she proved to have a good overview of (ii) the teacher's role and (iii) the content. She demonstrated a more student-centred approach and students were responsible for finding a solution to the problem by developing a gluten-free corn bread. Halfway through teaching the unit (activity 9 and 10, see Appendix), however, the teacher's confidence in students' ability to achieve their learning effects decreased. She 'took charge again' and her teaching became more teacher-centred. Consequently, students showed less ownership of the problem and less motivation to finish the unit. On reflection (member check), she attributed her decreasing confidence to two causes. The first was a lack of earlier experience with this new way of teaching macro-micro thinking using meso-levels; Figure 1 shows that repertoire can only be acquired (characteristic 5), and can only take place, when there is an earlier experience in terms of practical ability (characteristic 7) and actions (characteristic 6) in situations of the specific domain. Second she was personally

Social activity

Context-setting in a project team in developing food products (teacher's role as senior member)

a. Ability to act in class so that students feel ownership of the problem and can develop a product meeting the desired properties.

b. Ability to organise a flexible balance between student -centred and teacher-centred instruction.

Problem with product development meeting desired properties

c. Ability to teach problem-solving procedures in product development regarding research in structures-property relations using macro-micro thinking.

d. Ability to performe a teacher's role in facilitating a need-to-know basis

e. Ability to teach students how to use general research procedures during problem-solving in product development.

f. Abilities in creating, ordering, stucturing and anchoring new knowledge on the basis of existing knowledge of teachers and students in order to come closer to problem solution in

Macro-micro thinking using meso-levels in structure-property relations

g. Advanced ability to teach macro-micro thinking using meso-levels to explain and predict structure-property relations

Figure 4 Themes in teachers’ new repertoire related to (i) the context-setting, (ii) the teacher’s role and (iii) the content of a context-based unit overloaded in dealing with all new aspects of (i) the context-setting, (ii) the teacher's role and (iii) the new content together.

Verification of expertise: Verifying themes and theme descriptions in a broader field

Semi-structured interviews were analysed according to of the themes (a-g) and the dimensions (effect, actions, situations) in the description of these themes. For this verification, relevant fragments of the interviews were selected and classified within the dimensions of the themes. Further analysis of data led to confirmation of the themes and theme descriptions and did not lead to adjustments, supplements or specifications of the themes. The peer review procedure led to minor adaptations and further specifications of the theme descriptions to formulate themes more clearly. The data gave more insight into the relevance and importance of the themes from a teacher's point of view and the emotions involved when teachers changed their practice.

Teachers focused more on (i) setting the context and (ii) performing their new teacher's role than on addressing (iii) the new chemistry content of macro-micro thinking. In particular, the intended effect that students learn by developing a product faded away when the teachers started to discuss how to teach the unit in class. When the teachers reported their experiences of teaching context-based units, they largely mentioned their problems and solutions in (i) setting the context and (ii) performing their teacher's role; for example, organising student-centred instruction, motivating students to work in project teams, their own role in class when students worked in teams, etc. Teachers focused mostly on the organisational part of (i) setting the context and did not, for example, focus on guiding the students and making them own the problem.

Furthermore, carrying out general research procedures such as understanding literature, laboratory procedures, writing reports, etc. required more effort than expected. Four teachers (of the five) in the verification group focused on the practical and organisational problems surrounding these research procedures. Problem-solving procedures to develop a product with the desired properties disappeared into the background.

Additionally, when teachers reported on teaching context-based units for the first time and changing their teaching practice in class, they showed a lot of emotions. One teacher was not sure she would teach the unit next year, because she said: 'I have to do the innovation all on my own. I thought I was a good teacher, but this is too much change at once'. Teachers had a strong feeling of responsibility towards students achieving their learning effects. One teacher observed: 'I failed to make the students understand macro-micro thinking'. When they taught context-based units, they had a lot of concerns about whether students were able to achieve the intended learning effects or not. Teachers were insecure about what students learned and were supposed to learn (effects, Table 1). Another teacher mentioned being concerned about the students' preparation for higher education. He said: 'I still make sure that the students achieve all the learning goals from the old curriculum alongside the "new chemistry" just to make sure they would not fail at their next level of education'.

Summarising the findings of this analysis, we note that the themes were related to (i) the context-setting, (ii) the teacher's role and (iii) content of the context-based unit about macro-micro thinking in structure-property relations. This is shown in Figure 4. To facilitate teachers' acquisition of new domain-specific expertise in (i) setting the context, they need to become more able to enabling students to take ownership in solving the problem that is assigned (Theme a). In addition, teaching a context-based chemistry unit requires teachers acquiring new domain-specific expertise in structuring a different balance between student-centred and teacher-centred instruction in class compared with their conventional teaching (Theme b). Teachers require new domain-specific expertise to teach problem-solving in product development in class. For that, teachers require domain-specific expertise in demonstrating problem-solving procedures for product development (Theme c). The intended effect of giving students a problem is to motivate students to learn chemical content on a need-to-know basis. Therefore, teachers need new domain-specific expertise to perform (ii) a teacher's role to demonstrate problem-solving procedures and teach (iii) content on a need-to-know basis (Theme d). The ability to demonstrate problem-solving procedures on a need-to-know basis requires new domain-specific expertise in demonstrating general research procedures to find new knowledge in order to come closer to a problem solution (Theme e). Therefore, teachers need new domain-specific expertise in creating, ordering, structuring and anchoring new knowledge on the basis of existing teacher and student knowledge (Theme f). Since the content of macro-micro thinking using meso-levels is new to teachers, teachers need new domain-specific expertise in teaching macro-micro thinking (Theme g).

	Effect on students and teacher
a. Ability to act in class so that students feel ownership of the problem and can develop a product meeting the desired properties	• The teacher creates a learning environment where students become problem-owners by having the authority and responsibility to solve the problem
b. Ability to organise a flexible balance between student-centred and teacher-centred instruction	• The teacher determines the balance between student- and teacher-centred activities by organising and adapting activities depending on student input and stimulating the independent learning of students
c. Ability to teach problem-solving procedures in product development regarding research in structure-property relations using macro-micro thinking	• The teacher is more experienced in following product development procedures and general research procedures but does not have a straight solution to the problem. Teacher and students expand their knowledge and practice by trying to change the structure of a product to produce the desired properties
d. Ability to perform a teacher's role in facilitating a need-to-know basis	• The teacher follows the structure of the unit, the kind and order of activities that guide the students according to the need-to-know basis by offering information when the students need it to solve the problem

Table 1 Theme descriptions in teachers' new domain-specific expertise

Actions	Situation
• The teacher arranges for the problem to be assigned by an external authority • As a senior project member, the teacher approaches the students as project members in a project team and guides them to execute activities to find a problem solution • The teacher constructs an overview of the activities and procedures, monitors and guides the students to achieve the intended effect of the unit and values student contributions to discussions on decision-making in the product development procedures	• There is a clear division between the times when students execute their research activities alone and when the teacher is involved
• The teacher notices when the students need teacher involvement and when students can do the activities on their own • The teacher allocates time to monitor the learning process of students to gain confidence in students achieving the learning effects	• When the project team decides how an activity has to be carried out, the teacher responds quickly to adapt the planned activities to maintain the intended learning effects
• The teacher makes sure the students follow activities in product development that lead to problem solution • The teacher teaches the students knowledge about, and skills in, procedures in product development in the related context-setting by valuing students' contributions during discussions	• First activities in product development procedures are mostly induced by the teacher; later, students initiate more and determine the activities needed to solve the problem
• The teacher has a good understanding of the need-to-know basis and how it is processed in the structure of the unit to achieve the desired learning effects for students • The teacher respects and trusts the ability of the students to find the information they need to solve the problem without explicitly introducing the information to them	• When there are unexpected situations, the teacher has to be able to adapt the activities keeping the need-to-know basis intact

	Effect on students and teacher
e. Ability to teach students how to use general research procedures during problem-solving in product development	• The teacher succeeds in teaching students to execute experiments in a scientific way to gather information about (possible improvements of) the product
f. Abilities in creating, ordering, structuring and anchoring new knowledge on the basis of existing knowledge of teacher and students in order to come closer to problem solution in product development	• The teacher adds new information and insights to existing information, so students are able to identify missing knowledge to solve the problem
g. Advanced ability to teach macro-micro thinking using meso-levels to explain and predict structure-property relations	• The teacher is more experienced than students in explicitly using macro-micro thinking to relate the properties of a material to a certain level of underlying structures

Table 1 (continued)

Actions	Situation
• The teacher provides information on how to execute scientific research by gathering information from scientific sources, designing experiments, executing safe and accurate laboratory practice and formulating research reports • The teacher helps with and corrects general research procedures • The teacher discusses possible research procedures that could solve the problem • The teacher helps students in selecting sources of information, understanding text and tables, etc. • The teacher structures choices and results from experiments, leading to the next activity in the problem-solving procedure	• During group discussions on designing experiments to develop and improve products, the teacher guides students in general research procedures
• The teacher relates student contributions, reported results and conclusions and new information from activities to the problem solution • The teacher collects reported results in an orderly manner in a plenary session of the group to be able to see patterns in the results and draw conclusions • The teacher adds new steps to the procedure, gains information or results for the overall picture leading to problem solution	• During plenary group discussions, when results are reported, conclusions are drawn and decisions are made about the following step in the product development procedure, the teacher has to order, structure and anchor student contributions in the overall picture of the project
• The teacher indicates continuously on what macro-, meso- or micro-level the project team is referring to in the various activities and makes this explicit to the students • The teacher helps students to achieve their learning effect of macro-micro thinking by letting them formulate structure-property relations like ‘IF a product has structure X, THEN the product has property Y’	• During plenary group discussions, the teacher has to be continuously aware which macro-, meso- or micro-level students are referring to and make this explicit to the students using language consistent with the level

Discussion and Implications

This study focused on new domain-specific expertise that chemistry teachers need to acquire in order to teach innovative context-based units about macro-micro thinking in structure-property relations. This involves expertise in (i) the context-setting, (ii) the new teacher's role in class and (iii) the new content of macro-micro thinking. The new domain-specific expertise was described and summarised in Table 1 and Figure 4.

Expertise was defined as the ability to perform successfully in a specific domain. The new domain-specific expertise described in themes, formulated as abilities, needs to be acquired by the experienced chemistry teachers in this study to teach context-based units about macro-micro thinking in structure-property relations and to achieve the intended effects. Using data of teachers in different situations, we were able to describe new domain-specific expertise that teachers needed to acquire for teaching the innovative context-based chemistry units. The theoretical framework allowed a holistic view of the characteristics of expertise related to all aspects of the domain of teaching these units, acknowledging the interrelation of (i) the context-setting, (ii) the teacher's role and (iii) the new content (Figure 4). The results can be described and explained within this framework.

Seven themes (a-g) in this domain-specific expertise were determined. Each theme was described in three dimensions: effect, actions, situations (Table 1). Considering the explorative nature of this study, acknowledging the fact that each expert teacher performing in the domain of teaching innovative context-based units shows different successful actions to achieve students' intended learning effects and the completely new content of macro-micro thinking (Figure 2), this leads to a realisation that there are variety of ways of demonstrating this new domain-specific expertise. To describe teachers' abilities within the construct of PCK (Shulman, 1986; Shulman, 1987) and relate these abilities to aspects of a new pedagogical approach, new content using the definition of 'context' as the school situation, the construct of expertise allows us to describe the abilities needed within the interrelation of (i) the context-setting, (ii) the new teacher's role and (iii) the content of macro-micro thinking (Figures 3 and 4).

Although the theoretical framework provides a holistic view of expertise related to the interrelation of (i) the context-setting, (ii) the new teacher's role and (iii) content of macro-micro thinking (Figure 4), two new interrelated aspects emerged from our analysis: 1. experiencing cognitive overload; 2. dealing with teacher's emotions. These characteristics are important for the new domain-specific expertise needed for this teaching.

The cognitive overload (Cowan, 2001; Kalyuga, Ayres, Chandler and Sweller, 2003; Paas, Renkl and Sweller, 2003; Sweller, van Merrienboer and Paas, 1998) experienced by teachers in both case studies could be explained by the fact that, although they were experienced in teaching, they were beginners at teaching this context-based unit. This is related to the fact that the teachers were insecure (Smith and Strahan, 2004). Teaching this new context-based chemistry unit brought many new situations in which teachers required too much new domain-specific expertise. Consequently, they could not fall back on their routine actions and repertoire. To cope with this overload, the teachers fell back on their conventional role in class with a teacher-centred approach. As a result, the students also adapted and took their conventional role in class. The intended effects of the context-based unit, to let students feel ownership of the problem in a social activity, were not achieved. Falling back on routine actions and repertoire can be considered as a coping strategy to deal with the stress caused by work-related change (Brown, Ralph and Brember, 2002). This stress could be related to teachers being insecure about their own abilities and consequently having less confidence in student leaning effects (Evers et al. 2002). Teachers need to expand their repertoire, which involves expanding well-organised knowledge (characteristics 2&3, Figure 1) as a result of experience in classroom practice (characteristics 6&7, Figure 1) to act routinely and so prevent overload.

In addition, we found that emotions of teachers play an important role in teaching a context-based chemistry unit for the first time; emotions towards the curriculum innovation, teachers' insecurity about students and, indirectly, about their own performance. Teachers' emotions could not be described using the construct of expertise, as defined in this study. The construct of expertise lacks an affective characteristic necessary to describe teachers' emotions when participating in a professional development programme; for example, attitudes and emotions of teachers towards the innovations in chemistry education; the learning process of their students; and their own practice as a teacher. Attitudes and emotions could influence the teacher's perspective of experiences during classroom practice (characteristics 6&7, Figure 1) and consequently the development of knowledge to expand teachers' repertoire when acquiring new domain-specific expertise to teach this innovative context-based unit. How teachers' attitudes and emotions influence the acquisition of their expertise by their teaching of the context-based chemistry unit should be further studied.

A professionalisation programme based on one cycle of preparation, execution and reflection cannot facilitate the acquisition of all new domain-specific expertise. One cycle can only develop an initial basis for expanding new domain-specific expertise over a period of a few years. Based on this study, a professionalisation programme to teach context-based chemistry units about macro-micro thinking in structure-property relations could help teachers to avoid cognitive overload during the execution of the unit by expanding their repertoire to teach this context-based chemistry unit (Stolk, Bulte, De Jong and Pilot, 2009a; Stolk, Bulte, De Jong and Pilot, 2009b). This could result in teachers having a positive view of their experiences of teaching innovative context-based units. Consequently, teachers would have confidence, develop a positive attitude towards curriculum innovation and become motivated to acquire new domain-specific expertise in the following years as they teach the innovative context-based units.

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Appendix

	Activity	Description
Context-setting	1	In a videotape a senior scientist (external authority) introduces the problem of coeliac disease: some people cannot digest gluten in wheat bread but they can eat corn bread. Corn bread, however, does not have the same properties as wheat bread. . The senior scientist defines the problem of this project: the development of gluten-free corn bread with the same properties as wheat bread. This leads to a discussion between teacher and students about the development of a project proposal and the procedure for solving this problem. Students formulate initial ideas about the procedure. To examine what properties cause gluten in wheat bread students bake several breads of corn and variable amounts of wheat breads.
Definition of the problem in product development	2	Following the experiment in activity 1, students relate the variable amount of wheat to the properties of bread. This means searching for an alternative to gluten to add to corn dough to obtain at least the same properties of the bread.
	3	During a group discussion students adapt their project proposal for developing a gluten-free corn bread. They notice they need more knowledge about the given additives for gluten in order to choose one which enhances the properties of corn bread.
Extension and use of knowledge by using macro-micro thinking with structure-property relations	4	Hydrocolloids are known alternatives to all kinds of food products. In the light of an article about hydrocolloids as alternatives to gluten to improve wheat bread, students make a selection of hydrocolloids that might improve corn bread based on superficial arguments on macro-level.
	5	Several loaves of corn bread with different hydrocolloids are baked. This is the first attempt at gluten-free corn bread by students. The bread still does not have the desired properties. More knowledge about how gluten causes the desired properties in wheat bread is needed to obtain an argued selection of hydrocolloids.

Table 2 An outline of the innovative context-based chemistry unit about macro-micro thinking in structure-property relations, including the assigned problem to solve and activities to be performed by students to develop gluten-free food products

Activity	Description
6	Students are provided with a second article which gives detailed information about the baking process of wheat bread. Using the information in the article students search for more knowledge about the elastic property caused by structures at a meso-level containing gluten to obtain more information for arguments to select hydrocolloids.
7	To understand the second article, students need to develop a meaning for the core concepts 'structure' and 'property', A series of photos evokes the students' intuitive ideas about these essential concepts.
8	A group discussion about information of the given article in activity 6 leads to the next step: carrying out experiments like the ones presented in the article about the baking process of bread. These experiments are necessary to understand which structures at a meso-level containing gluten are related to the elastic property of bread and how to select possible hydrocolloids to be added to corn flour as an alternative to gluten.
9	Students carry out two additional experiments with corn dough containing different hydrocolloids and variable amounts of these hydrocolloids. The obtained results do not point towards one conclusion. It is expected that more knowledge will be needed about the structures at meso-level containing gluten networks and the way these structures are built up for an argued selection of hydrocolloids to add to the corn dough.
10	A third article is introduced containing information about the chemical structure of gluten (zooming into the structures at meso-level of activity 9) as strangled long polymers which can form an elastic network.
11	In the light of this information criteria can be derived for selecting hydrocolloids as an alternative to gluten. Examples are: the hydrocolloids must form long hydrophilic chains; they must have a small number of interconnections; they must have long side groups.

Table 2 (continued)

	Activity	Description
	12	The properties caused by the selected hydrocolloids at macro-level are tested in a second experiment. Students bake corn breads containing the selected hydrocolloids. Students explain the results using the information in the articles.
	13	Students give each other feedback on their formulated explanations about structure-property relations in bread.
Reflection on product development procedures and thinking process of macro-micro thinking	14	During a group discussion, questions are addressed to the students about the purpose of their project. Students are motivated to reflect on their knowledge about product development procedures and their macro-micro thinking process in structure-property relations.
Reflection and transfer	15	To (re)construct the thinking process of macro-micro thinking, students have to make the results of the product development procedures explicit in a conceptual schema of structure-property relations.

Table 2 (continued)

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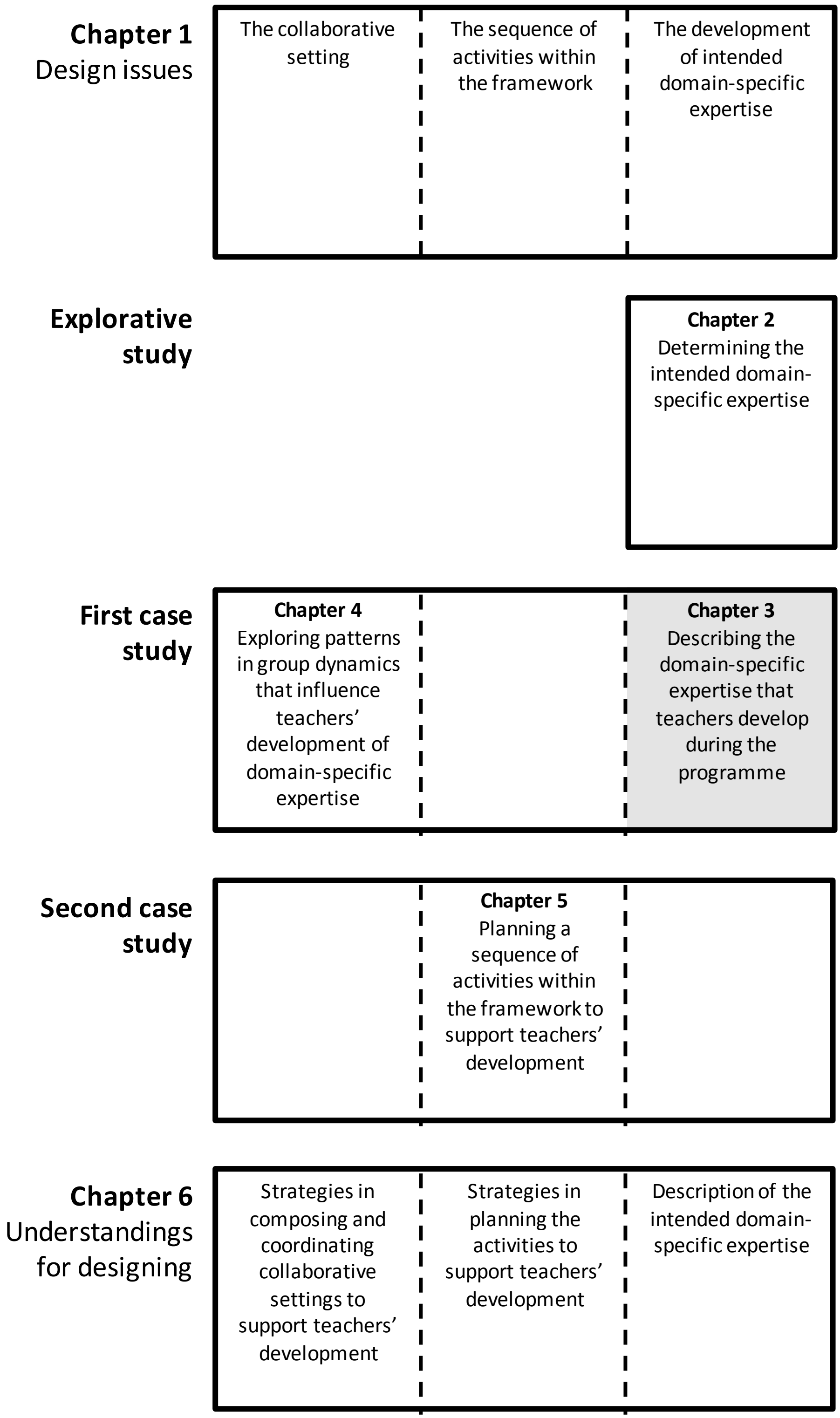
Chapter 1
Design issues
The collaborative setting
The sequence of activities within the framework
The development of intended domain-specific expertise
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Chapter 2
Determining the intended domain-specific expertise
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Exploring patterns in group dynamics that influence teachers' development of domain-specific expertise
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Strategies in planning the activities to support teachers' development
Description of the intended domain-specific expertise

Chapter 3

Chemistry Teachers' Development of Domain-specific Expertise in a Professional Development Programme[1]

Abstract

This study aims to evaluate the shared domain-specific expertise that teachers developed when they participate in a professional development programme, in which they teach a context-based chemistry unit in a collaborative setting. A case study is conducted in which a group of six teachers developed their domain-specific expertise in terms of context-setting, performing the new teacher's role and teaching new content. The results show that the teachers acquired newly shared expertise in setting the context and performing the new teacher's role, but only slightly expanded this new expertise. Teachers did not develop newly shared expertise in teaching the content of macro–micro thinking. In addition, it was found that the organization and management of the project teams in class hindered the development of domain-specific expertise in teaching the new content. The implications of these results for designing a professional development programme are discussed.

[1] This chapter is submitted as:

Dolfing, R., De Jong, O., Bulte A.M.W., Pilot, A., Vermunt, J.D. (*submitted*). Chemistry Teachers' Development of Domain-specific Expertise in a Professional Development Programme.

Introduction

Redesigning science curricula in terms of context-based, competence-based or inquiry-based programmes causes a change in teachers' domain of practice from teaching the conventional curriculum towards teaching the new curriculum. This often implies the teaching of new domain-specific content, for example in biochemistry, material science, nano-science and so forth, that is not part of a teacher's regular expertise (Bulte, Westbroek, de Jong and Pilot, 2006; De Putter-Smits, Taconis, Jochems and Van Driel, 2012; Lee, Hart, Cuevas and Enders, 2004; Pilot and Bulte, 2006; Wesselink, de Jong and Biemans, 2010). In addition, it involves a new role for the teacher in relation to their students.

The successful implementation of such new curricula thus requires that teachers develop new domain-specific expertise with respect to the new curriculum, that is not part of the commonly shared expertise among teachers (Verloop, Van Driel and Meijer, 2001), developers and researchers. This involves expertise in effective teaching strategies, practical knowledge, and rules of thumb (Wieringa, Janssen and Van Driel, 2011), which would be partly tacit and is often developed through experience. Therefore, it is required that a newly domain-specific expertise, for example through personal experience, becomes explicit and/or demonstrated in order to be shared among teachers, as stated by Breu and Hemingway (2002).

The development of this new expertise preferably takes place in professional development programmes in which teachers, developers and researchers work together to design, implement and evaluate curriculum materials in co-design processes (Penuel, Roschelle and Shecht, 2007). Co-design involves highly-facilitated, team-based processes in which teachers, researchers, and developers work together to design an educational innovation, realize the design in one or more prototype units, and evaluate each prototype's significance for addressing a concrete educational need. Working together in collaborative settings is seen as a promising strategy for teacher learning and development (Brouwer, 2011; Brown and Duguid, 1991; Butler, Lauscher, Jarvis-Selinger and Beckingham, 2004; Swan, Scarbrough and Robertson, 2002; Vescio, Ross and Adams, 2008), for educational innovation (Bakkenes, Vermunt and Wubbels, 2010), for school improvement (Harris and Jones, 2010) and for the teaching and development of curriculum units (George and Lubben, 2002; Whitcomb, Borko and Liston, 2009).

Several initiatives describe how teachers develop expertise when they teach context-based units in collaborative settings (Butler et al., 2004; George and Lubben, 2002; Handelzalts, 2009; Voogt et al., 2011; Whitcomb et al., 2009). More specifically, Stolk et al. (2012) described a framework for teachers' professional development to empower teachers to teach context-based chemistry units. Often in such programmes, teacher learning involves the choice of context, a new teacher role in relation to their students, or the studies investigate the teachers' self-regulation and empowerment in curriculum innovations. Furthermore, professional development can be directed to the teachers' learning of new content in relation to, for example, nanotechnology (Hingant and Albe, 2010; Tuvi-Arad and Blonder, 2010). Little is known, however, about the simultaneous development of newly shared domain-specific expertise with respect to a context-setting, to a new teachers' role and to new content when teachers are involved in such a professional development programme.

The aim of the present study is to evaluate what newly shared domain-specific expertise teachers develop when they participate in a professional development programme, that is based on the framework of Stolk et al. (2012), to teach an exemplary context-based chemistry unit in a collaborative setting. The results will provide insight into the balance of teachers' development of domain-specific expertise within the programme, in terms of the three interrelated domain-specific aspects of context-setting, teacher's role, and the new content. This study will also identify possible difficulties when teachers develop newly shared domain-specific expertise. These understandings will assist in further research about designing professional development programmes for this type of context-based curricula.

In describing the new domain-specific expertise teachers' development, the following sections are presented: (1) the theoretical background of analysing and describing the teachers' domain-specific expertise they develop during the programme; (2) the categories of domain-specific expertise for teaching the context-based chemistry unit; and (3) the collaborative setting in which this study was conducted.

Teacher's development of domain-specific expertise

According to Sternberg's model of expertise development (Ericsson, Charness, Feltovich and Hoffman, 2006), domain-specific expertise can be defined as 'the ability to perform successfully in a specific domain' (Ericsson et al., 2006; Sternberg, 1999a; Sternberg, 1999b; Tynjälä, 1999). Based upon this definition, the teachers' domain-specific expertise was described as 'the ability to teach a context-based chemistry unit to achieve the effects as intended in the curriculum innovation' (cf. Chapter 2, Table 1).

These effects initially involve student learning outcomes which are specific for this innovation. The effects also involve more general outcomes in the short and long terms, such as enhancing student interest in science, and fostering the level of chemistry education in secondary schools (Ryder and Banner, 2011). To analyse and describe teachers' domain-specific expertise, a construct was developed (Dolfing, Bulte, Pilot and Vermunt, 2012). This construct consisted of interrelated components of expertise representing the characteristics of an expert (Ericsson et al., 2006;

Sternberg, 1999a; Sternberg, 1999b; Tynjälä, 1999). The construct is presented in Figure 1. In this study, this construct was used to describe teachers' domain-specific expertise in several moments during the professional development programme, and to monitor the development of domain-specific expertise. This will be elaborated below.

To perform successfully in a specific domain of teaching the chemistry curriculum, teachers need advanced processes in teaching to recognize and define (learning) problems of students, to use learning materials and prepare lessons, to act and react in interaction with students, and to evaluate what the effects of their teaching was on their students. These processes are represented as a processor component in domain-specific expertise (Figure 1). Expert teachers are often not aware of these processes. They often are not accustomed to make these processes explicit, to explain why to act in a certain way, and to explain what effects to achieve (Dunphy

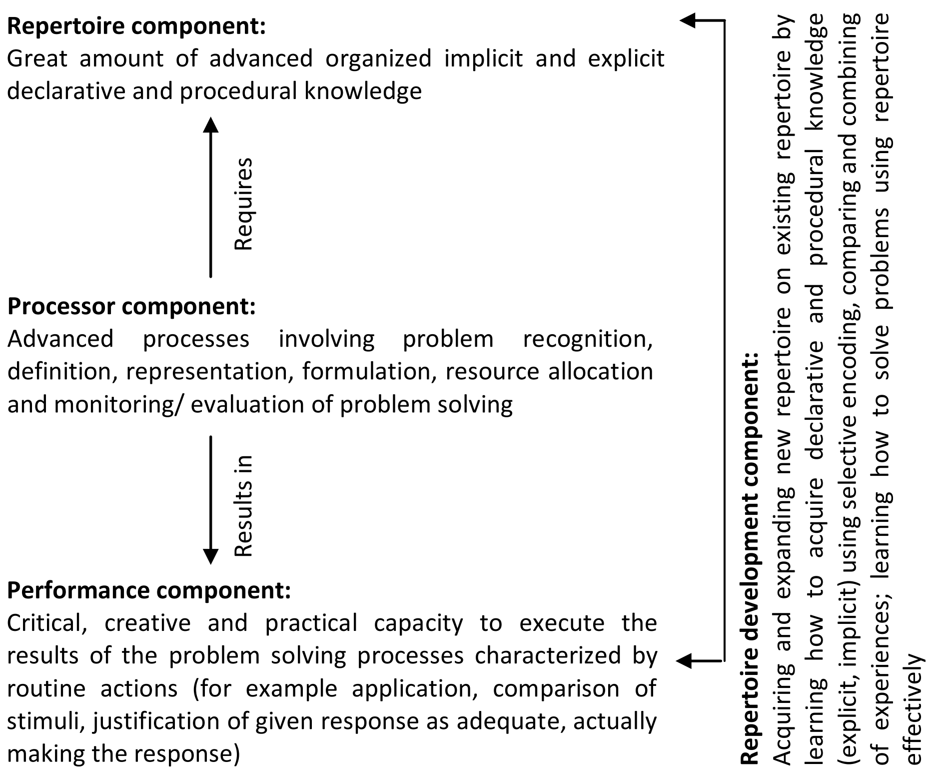

Figure 1 Interrelated components in the construct of teachers' domain-specific expertise

and Williamson, 2004). However, the results of teachers' processes in domain-specific situations are demonstrated in their performances. The performance component of expertise (Figure 1) means that a teacher has the capacity to demonstrate the results of their processes in teaching.

To use advanced processes in teaching, a teacher needs a repertoire of advanced explicit and implicit declarative and procedural knowledge (repertoire component, Figure 1) of pedagogical approaches and teaching strategies, student learning processes in the domain and in the school situation. Teachers use their initial repertoire of knowledge in order to solve problems in domain-specific situations and develop their repertoire by new experiences when reflecting on the effects of their actions (Clarke and Hollingsworth, 2002). This is represented in the construct as the repertoire development component.

Based on these components of expertise, teachers' development of domain-specific expertise can be defined as the acquisition and expansion of a new repertoire through performance and reflection on processes in new domain-specific situations. This involves acquiring and expanding declarative and procedural knowledge (implicit and explicit), using selective encoding, comparing and combining experiences and learning how to solve problems by using their initial repertoire.

Referring to the repertoire component and performance component in the presented construct of expertise, teachers' domain-specific expertise can be analysed and described from data sources, in which teachers make their expertise explicit, e.g. a mind map, discussions between teachers (Tigelaar, Dolmans, Meijer, De Grave and Van Der Vleuten, 2008) or logs (Bakkenes et al., 2010). Their implicit expertise can also be interpreted from data sources in which they demonstrate their repertoire when performing, for example, in adapted lesson materials and plans, assessments and video recordings of lessons. The domain-specific expertise can be described in terms of the sub-dimensions of the intended effects on students (effect) and teacher's actions (actions) in domain-specific situations (situation) (Chapter 2; Dolfing, Bulte et al., 2012).

For a successful implementation of this particular curriculum innovation, it is required that teachers not only develop their expertise personally. The expertise they develop, needs to become explicit and/or demonstrated in order to be shared and become part of the commonly shared expertise among teachers (Verloop et al., 2001). In this study, it was considered that when two or more teachers develop their expertise in the same category by collaboration, this expertise is considered to involve newly *shared* expertise. The categories of the intended domain-specific expertise to teach context-based chemistry education are described in the next section.

A curriculum innovation requires experienced teachers to change their teaching practice and to perform in for them atypical situations. These teachers could become

Social activity

i Context-setting of a project team solving a problem in product development

a. Ability in teaching problem-solving procedures in product development regarding research in structure-property relations using macro-micro thinking

b. Ability in teaching according to facilitate a need-to-know basis

c. Ability in teaching students how to use general research activities during problem solving in product development

ii Teacher's role as senior member of the project team

d. Ability in acting in class so that students feel ownership of the problem to develop a product meeting the desired properties

e. Ability in organizing a flexible balance between student-centred and teacher-centred instruction

f. Abilities in creating, ordering, structuring and anchoring new knowledge on the basis of existing knowledge of teacher and students; so one comes closer to a problem solution in product development

iii Macro-micro thinking using meso-levels in structure-property relations

g. Advanced ability to teach macro-micro thinking using meso-levels to explain and predict structure-property relations

Figure 2 The domain-specific expertise that teachers require in order to teach a context-based chemistry unit about macro–micro thinking in structure–property relations, in terms of (i) setting the context in class, (ii) performing the new teacher's role and (iii) teaching the new content (chapter 2; Dolfing, Bulte et al., 2012) uncomfortable when these atypical situations arise in their classroom. Their emotions can then have a significant impact on their performance. These emotions can also significantly influence the development of their domain-specific expertise through (de)motivation, self-efficacy, stress, beliefs and attitudes. Feelings of stress and incompetence may reduce teachers' self-efficacy and self-esteem. These feelings may lead to the development of coping strategies to avoid these feelings. This may lead thus to specific difficulties, when teachers are implementing the new curriculum and developing new domain-specific expertise.

Context-based chemistry education and the intended development of domain-specific expertise

This study was carried out in the curriculum innovation of context-based chemistry education in the Netherlands (Bulte et al., 2006; Meijer, Bulte and Pilot, 2009; Pilot and Bulte, 2006; Prins, Bulte and Pilot, 2008; Stolk, De Jong, Bulte and Pilot, 2012). This curriculum innovation involved the design of innovative context-based units. In addition, teachers participated in professional development programmes, in which they were intended to develop the required domain-specific expertise in a collaborative setting (Domitrovich et al., 2009). This domain-specific expertise involved the new aspects of (i) setting a context in class, (ii) performing the new teacher's role and (iii) teaching new content (Figure 2).

The abilities in domain-specific expertise which teachers need to teach the particular context-based chemistry units in this study were analysed and described in Chapter 2 (Dolfing et al. 2012). These descriptions are not saturated yet, considering the early stage of curriculum innovation. Figure 2 represents these abilities in relation to the new aspects in teaching context-based chemistry units.

In exemplar units of this curriculum innovation the new content and teacher's role in relation to students are determined by the context setting (Meijer et al., 2009; Prins, Bulte and Pilot, 2011; Westbroek, Klaassen, Bulte and Pilot, 2010). The 'context' in context-based education is conceived as the setting of a social activity (Figure 2) within which the student's behaviour and mental experiences are situated and which uses the relationship between situated background knowledge and specific language (Gilbert, 2006; Gilbert, Bulte and Pilot, 2011).

In this particular curriculum innovation, the context-setting requires teachers to organise and manage project teams consisting of students and a teacher who have to solve a problem in product development (i, Figure 2) . Students need the new content as a tool to solve this problem (need-to- know principle, cf. Bulte et al., 2006). To gain information, students need to perform general research activities. In the conventional curriculum, teachers are often used to teach the chemistry content directly to the students, or they use contexts as examples to illustrate how the content is used in practice. In the new curriculum, teachers need to develop the understanding that the problem as presented in the context determines the content that is being taught. The students in the project teams learn the content when they need it as a tool to solve a problem.

In the context-based curriculum, the teacher performs the role as the senior member of the project team (ii, Figure 2) and guides the students in product development procedures. This means that students are motivated to take ownership of the problem. Consequently, teachers use different pedagogical approaches, stimulating students' self-regulated learning to create a different balance in student- and teacher-centred instruction compared with teaching of the conventional curriculum. The teacher also helps students to create, order, structure and anchor new knowledge on the basis of existing knowledge, for example gained by performing the research activities, by keeping an overview of students' performance of activities, monitoring student learning through assessments, giving instructions to students in class, and so forth.

In the conventional curriculum teachers have the role of the expert who knows the answers to the questions in the book, knows what conclusions are drawn from general experiments and lab activities, and so forth. The teacher often values student answers to questions from the teacher or from the book in a way of 'right' or 'wrong' (Mortimer and Scott, 2003). However, in the new curriculum teachers should develop expertise in acting as a senior member of the project team, they do not know the answers or problem solution. Instead, they have to become more experienced in, for example, performing research activities, setting up experiments and finding literature to gain more knowledge about materials and products, and they provide students with overviews and summaries, help students to relate conclusions of experiments to theoretical knowledge from books, guide students in formulating questions and searching on the internet for more information, organise lab activities in class, monitor student learning during the problem-solving processes, and so on. This constitutes the new teaching role, and is considered as a huge shift in terms of teaching practice.

The new content of the unit (iii, Figure 2) involves macro–micro thinking using meso-levels in structure–property relations (Meijer et al., 2009). For chemistry teachers in the Netherlands, this content is new in their classroom teaching. In the conventional curriculum, macro–micro thinking is directed towards learning about particles such as molecules and atoms (micro-level), and direct relations to properties at the macro-level (Taber, 2009). This is represented in Figure 3 (Dolfing, Boerwinkel, Van Mil, Vollebregt and Klaassen, 2012). The context involves the social activity of product development. The properties of the product material at the macro-level are mostly explained using structures at levels between the macro- and micro-levels. Therefore, a product is considered as a structure (macro-level) consisting of several nested interrelated substructures (meso-levels). This is represented in Figure 4.

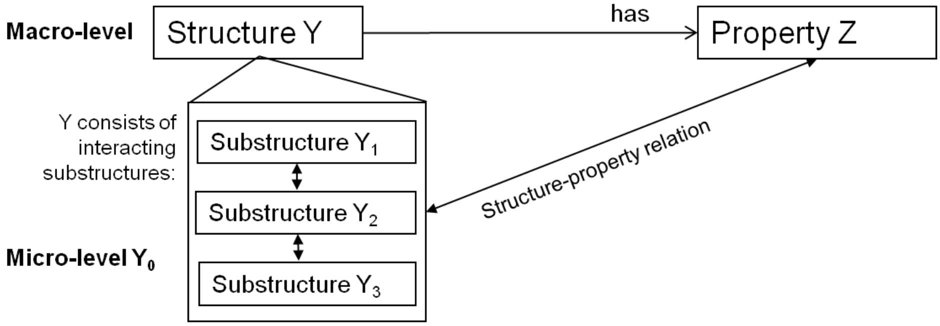

Figure 3 Conceptualization of macro–micro thinking in the traditional chemistry curriculum

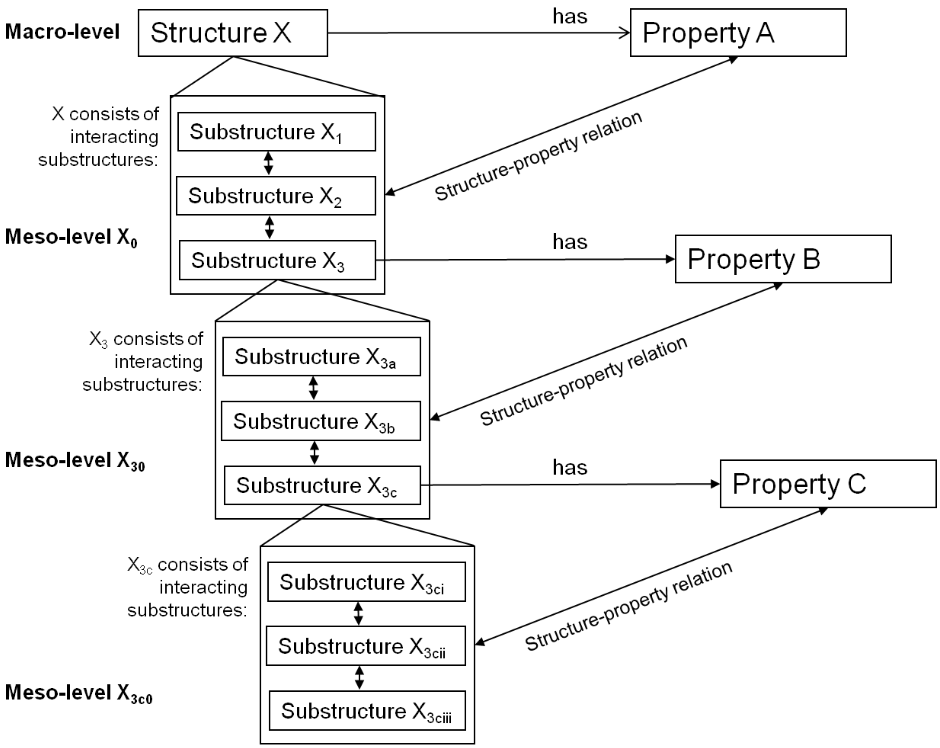

Figure 4 Conceptualization of macro–micro thinking using meso-levels in structure–property relations

In the context-based chemistry unit, students start with the implicit use of macro–micro thinking when addressing the problem. By doing this, their knowledge about structure-property relations is expanded during the project, when they explain and predict the properties of the product on the macro-, meso- and micro-levels. Students make their macro–micro thinking explicit by formulating the structure–property relations in sentences, such as: 'IF a structure X consists of interacting substructures X_1, X_2, X_3, etc., THEN structure X has property A'. Continuing to zoom in further onto structure X in Figure 4 would result in the following structure–property relations: 'IF a substructure X_3 consists of interacting substructures X_{3a}, X_{3b}, X_{3c}, etc., THEN substructure X_3 has property B' and 'IF a substructure X_{3c} consists of interacting substructures X_{3ci}, X_{3cii}, X_{3ciii}, etc., THEN substructure X_{3c} has property C'.

The set of 'IF...THEN....'-sentences represent the system of nested structures and properties. The sentences result in the explicit formulation of a 'mental map' of macro–micro thinking using meso-levels with regard to structure–property relations. Depending on the type of problem, a number of different meso-levels may be relevant, and a certain set of structure–property relations will be necessary to solve the product development problem at hand. Structures of atoms and/or ions at the micro-level should only be used when it is necessary to address the problem of developing a product which has the desired properties.

To be able to teach the context-based unit, teachers need to be able to teach macro–micro thinking using meso-levels in order to explain and predict properties on the macro-level using underlying interacting substructures.

The professional development programme

Stolk et al. (2012) described a framework for teachers' professional development to empower teachers to teach context-based chemistry units (Stolk, De Jong, Bulte and Pilot, 2011; Stolk et al., 2012). Referring to Galperin's theory for the internalisation of actions (Arievitch and Haenen, 2005), the framework consists of three phases:

- Preparation phase in which teachers prepare the unit to share initial expertise and acquire new expertise;
- Instruction phase in which teachers instruct the unit in the teacher's own school situation to apply and expand the new expertise;
- Reflection phase in which teachers reflected on teaching actions and effects on students to expand and share the new expertise.

Initial to the programme (initial phase), conditional functions have to be achieved for teachers' development. For example in the initial phase teachers are stimulated to reveal their initial expertise. In addition, within each phase of the professional development process, functions are fulfilled by the teachers for their development to teach context-based units successfully (e.g. Appendix). For example, an exemplar function is that teachers are facilitated in formulating their own learning goals or in exploring strategies for teaching the context-based unit, examples should be provided, and conditions need to be presented for using the unit in class. In order to enhance the development of the shared expertise, teachers participated in a professional development programme based on this framework.

By teaching context-based chemistry units in such a collaborative setting, it is often assumed that teachers can acquire and expand their shared expertise in terms of all abilities as described (a-g, Figure 2). However, in this study this assumption was evaluated. In short, this study of the development of teachers' domain-specific expertise is described by focussing on the analysis of the personal and shared expertise at three moments during the professional development programme:

- at the beginning, when they have their initial expertise;
- at the interface of preparation and instruction, when they acquired new expertise;
- at the end when they have expanded their expertise during reflection upon their teaching actions and the effects achieved with their students.

Scope and Research Question

The present study aims to evaluate the new personal and shared domain-specific expertise that chemistry teachers develop when they participate in a professional development programme to support teachers in the curriculum innovation of context -based chemistry education. This involves the simultaneous development of expertise in all three aspects of teaching context-based chemistry units (Figure 2), with respect to (i) context-setting, (ii) the new teacher's role and (iii) the new content on materials science using macro-micro thinking and structure-property relations. The research question was formulated as:

What domain-specific expertise do teachers develop when they teach a context-based chemistry unit about macro–micro thinking in structure–property relations in a collaborative setting?

The results will provide insight into the balance between the learning of these three interrelated aspects of new domain-specific expertise within the professional development programme and the difficulties when teachers develop new domain-specific expertise in a collaborative setting. In addition, taking teachers' feelings and emotions into account due to the changing domain, this study will also identify possible difficulties when teachers develop this new expertise.

Method

A case study was conducted involving six teachers, guided by an experienced coach, participating in a professional development programme, based on the framework of Stolk et al. (2012). The professional development programme involved that teachers prepared the unit collaboratively. They then instructed the unit individually in the teachers' own school. Finally the teachers collaboratively reflected on their teaching actions and the effects on students. The programme, including the phases, functions and activities, is represented in the Appendix. The activities within the phases and the role of the coach will be elaborated below.

Initial to the programme, teachers were motivated to participate in the professional development programme by referring to their personal interests in the curriculum innovation, problems in their school situation that they wanted to solve by teaching the context-based units. They appreciated the chance to work together and share experiences with teachers from other schools. In addition, they were motivated to contribute to and advice about the curriculum innovation. Teachers were also motivated by providing remuneration and offering them intensive coaching and professional development to prepare for the upcoming curriculum innovation. Prior to the programme, teachers were asked to provide a mind-map of associations with context-based chemistry education, lesson plans and assessments from their conventional teaching that, according to them, included aspects of context-based chemistry education.

The preparation phase consisted of five meetings of two hours each over three months. Before every meeting teachers were asked to prepare themselves individually for the activities of the upcoming meeting. The process of preparation involved teachers adapting the unit to their own school situations, designing lesson plans and student assessments. Additionally, the teachers defined their own learning goals in order to demonstrate what expertise they had acquired and wanted to expand during the instruction and reflection phase.

During this preparation phase, the coach guided the teachers by leading their discussions and supporting them in understanding the learning effects that the students had to achieve and the actions they could take to achieve these effects in their own school situations. The coach guided the teachers by sharing his own experiences and/or gave them additional literature about teaching strategies and pedagogical approaches that they could use.

The instruction phase consisted of approximately 10–12 regular lessons, depending on the teachers' own school situation. During the instruction phase, teachers discussed their teaching actions and the effects on students they achieved in a midway evaluation meeting. Based on the discussions in this meeting, the teachers decided individually whether or not they needed to change their lesson plans and teaching actions during the second part of the instruction phase. Besides they reported their experiences individually in a weekly log.

The reflection phase involved two meetings; one immediately after the instruction phase, and one three months after instruction. In these meetings, teachers reflected on their teaching actions and the effects which had finally been achieved by students. In the meeting immediately after instruction, teachers expressed and shared their emotions, problems and moments of success, they had experienced during the instruction. In the last meeting, the teachers looked back on the learning goals they had defined for themselves with respect to the development of their domain-specific expertise. They expressed their achievements by describing how they would adapt the lesson material and perform their teaching actions in order to achieve the intended student effects as intended when they would teach the unit again.

Participants

The teachers in this group had two, three, five, seven, nine, and 35 years of experience on teaching in secondary schools. They came from four different schools. Two pairs of teachers came from the same school. One pair of the teachers had taught a previous version of the particular context-based chemistry unit on two previous occasions. The other four teachers did not have any experience of teaching context-based chemistry units. The teachers all taught the same conventional curriculum, which was the nationally standardized chemistry curriculum in the Netherlands.

Teachers*	School	Years of Experience		
		Conventional curriculum	Context-based education	Teaching the particular unit in this course
Sue	School A	5	0	0
Tina	School B	3	0	0
Chad	School C	35	2	1
Tony	School C	2	1	1
Rich	School D	9	1	0
Rose	School D	7	0	0

Table 1 Characteristics of teachers who participated in the case study
** all pseudonyms*

The coach had been one of the pioneers in the early days of this particular curriculum innovation. He was one of the first designers of context-based chemistry units in the Netherlands and taught these units at his own school. Before participating in this study, the coach had two years of experience in coaching to help teachers to teach context-based chemistry units. The students were 14 or 15 years old, involved in pre-university education and had similar educational backgrounds. They had not previously participated in context-based chemistry education.

Materials

The unit taught by the teachers involved setting the context, during which an artist assigned project teams the task of developing a composite material for making artefacts. The desired properties of the composite material were strength and compactness, as it had to travel around in an exhibition; it also should not absorb grease from the fingers of visitors.

The product development procedure consisted of two cycles of gaining information, developing, testing and improving the product. The project teams needed to know more about the structure–property relations of several materials. They had to carry out general research activities, such as reading literature and conducting experiments to find out more information about, for example, clay, paper and gypsum. Then they formulated the results in terms of structure–property relations, such as: 'IF a material consists of parallel-orientated fibres, THEN the material has a high tensile strength'.

Data collection

Data collection and analysis followed a case study approach (Creswell, 2007). The sources of data are shown in the Appendix of this chapter. Data sources in which teachers made their expertise explicit involved: Mind maps: teachers' associations with context-based chemistry education about macro–micro thinking in structure–property relations; Video recordings of discussions in meetings; Teachers' logs during instructions (e.g. Bakkenes et al., 2010). Data sources in which teachers demonstrated their expertise in their performance involved: Video recordings of two lessons during instruction; The designed or adapted lesson materials, lesson plans and student assessments.

In addition, during the instruction phase, the first or second lesson was recorded. After the lesson, the teacher and researcher watched the video to stimulate teachers' sharing of expertise. During this video recall procedure (Welsh and Dickson, 2005), the teacher was interviewed about his/her experiences, his/her acquisition of new expertise during the preparation phase and his/her plans to instruct the unit in class during the next lessons. Data sources collected during the programme are presented in the Appendix.

Data analysis

In order to describe the domain-specific expertise that the teachers had developed, data sources for every single teacher were selected, combined and analysed in a qualitative way and in a chronological order (Meirink, Meijer and Verloop, 2007). To analyse teachers' initial domain-specific expertise, the video recordings of the first meeting were used as a primary data source. The first mind-map, lesson plans and assessments from their conventional teaching, which they delivered prior to the programme, were used as secondary data sources. In order to analyse teachers' acquired domain-specific expertise, the video recordings of the meetings during preparation and the interviews at the interface of preparation and instruction were used as a primary data source. The second mind map, adapted unit, lesson plans and student assessment, which teachers delivered after the preparation phase, were used as secondary data sources. To analyse teachers' expanded domain-specific expertise, the logs and video recordings of meetings in the instruction and reflection phase were used as primary data source. The video recordings of the lessons, the third mind map, final lesson plans and student assessments were used as secondary data sources.

From the primary data sources, quotations were selected which contained information about teachers' abilities in terms of explicit and implicit expertise about teaching actions (actions), which they used to achieve the intended student effects (effects) when teaching a context-based unit on macro–micro thinking in structure–property relations (specific domain). In addition, these quotations included the emotions which the teachers had explicitly revealed, that possibly had influenced the development of their domain-specific expertise.

Quotations were categorized, according to the three aspects of the domain-specific expertise as described in Figure 2, as follows: (i) setting the context, abilities a -c; (ii) the teacher's role, abilities d-f; and (iii) content, ability g. Then the series of quotations in each category were interpreted by categorical aggregation (Stake, 1995) using the secondary data sources. By accumulating, combining, and aggregating interpretations of single quotations, the development of expertise in each category emerged from the data. The development of teachers' personal expertise were then described and compared. When two or more teachers acquired and expanded expertise in the same category, this expertise was considered as newly shared domain -specific expertise.

Teachers often did not, or only partly make, their expertise explicit in the primary data sources. However, then teachers did reveal their expertise in their performance, which could be interpreted from quotations in the secondary data sources. For example, the secondary data sources as video recordings of the lessons, were used to interpreted the expertise which teachers expressed during the meetings and in their logs. In addition, quotations about 'how to organize the project teams in class' were

Ability	**Initial to programme**	**Preparation**	**Instruction & Reflection**
Intended	+/-	O	●
a	+ All	O All	● Sue
			O Rich, Chad Tony, Rose, Tina
b	+ Chad	O Rich, Chad, Sue	● Sue
	- Tony, Rose, Tina Sue, Rich	- Tony, Rose, Tina	O Rich, Chad Tony, Rose, Tina
c	- All	O Tony, Rose, Tina Sue, Rich	● All
		- Chad	
x	+ Sue	O All	O All
	? Tony, Rose, Tina Rich, Chad		
d	+ Sue	O All	O All
	- Tony, Rose, Tina Rich, Chad		
e	+ Tony, Rose, Sue	O All	● Sue
	- Rich, Chad, Tina		O Rich, Chad Tony, Rose, Tina,
f	- All	O All	● All
g	+ Tony, Tina, Chad, Sue	+ All	+ All
	- Rich, Rose		

Table 2 Overview of the results

- *teachers do not have an initial expertise;*
+ *teachers do have an initial expertise;*
  teachers developed personally by sharing the available initial expertise;
o *teachers acquired new additional expertise;*
● *teachers expanded their newly acquired expertise;*

frequent, so it was decided to formulate an additional 'ability x': 'Ability in organizing and managing project teams in class'. This meant that the a-priori set of abilities of the domains-specific expertise (Figure 2; Dolfing et al, 2012) needed to be expanded. This is elaborated in the next sections.

The interpretations of quotations were validated in a peer review procedure between the author of this thesis and an independent colleague researcher, in which the coding, categorization and interpreting of critical quotations were discussed to reach agreement about the results (Creswell, 2007).

Results

Table 2 represents a broad overview of the results. The symbols in the Table are explained in the subscript. This table shows teachers' initial, acquired and expanded expertise within the categories in terms of the abilities a-g and x. Initially, some teachers did have an initial expertise in one or more categories. As shown in Table 2, Tony and Chad had initial expertise in some categories, because they taught the unit in a previous occasion. However, other teachers also demonstrated the intended initial expertise in one more categories. All teachers could share initial expertise during the preparation phase, and it was not expected that the development of expertise of Tony and Chad were different from other teachers.

Teachers do learn personally, but they do not always develop new additional domain-specific expertise. Newly shared expertise was developed, when two or more teachers acquired and expanded expertise within the same category. The next sections provide a more detailed and qualitative description of the development that occurred in the collaborative setting.

Teachers' development in 'Setting the context in class'

Teachers' development in (i) setting the context in class involved the acquisition and expansion of expertise in the categories of ability a-c and x (Table 2). The development of the initial, acquired and expanded expertise of the teachers is described in terms of these abilities.

Initial to the programme, all teachers showed an awareness that in this context-based chemistry education the content was set within the context of the social activity of product development with a focus on macro–micro thinking in structure–property relations (Table 2: ability a). They showed understanding that setting the context involved the teacher in giving examples of the application of the content within product development. These examples would illustrate the content of molecules and to make it more meaningful and interesting for the students.

For example, when Sue introduced herself in the first meeting, she shared that she did not have any experience in teaching context-based chemistry education. However, in her first mind map she wrote that she associated context-based chemistry education with a context-setting in which students were assigned to solve a problem in the use of materials. In addition, she wrote that the context-setting should evoke a motive to explain phenomena when using these materials. In her lesson plan, she described an example she used to teach macro-micro thinking to her students. She referred to a problem of an iron drawbridge that did not close when the weather outside was hot. She wrote that she explained to the students that iron atoms move faster when it is hot outside, causing dilatation of the construction. In addition, in her lesson plan Sue planned to tell the students that they needed to solve this problem by searching on the Internet to gain information. The students were assigned to write down their solutions in a report. Sue valued the report with a mark.

Although she did not make it explicit in the meeting, Sue demonstrated that she had initial expertise in terms of having the ability to teach problem-solving procedures in product development. However, this procedure was not structured in clearly defined steps or activities. Her lesson plan included a problem for students, assigning them to search for information on the Internet to solve this problem. In this way, Sue demonstrated that she used this pedagogical approach in her conventional teaching. Other teachers demonstrated similar information about their expertise in their lesson plans and mind maps, although they were not aware that this initial expertise was useful when teaching context-based chemistry units.

Only Chad demonstrated an initial awareness of the intended effects on students of learning on a need-to-know basis in context-based chemistry education (Table 2: b). In his mind map, he associated context-based education with the 'need-to-know' principle, which meant, according to Chad, that the teacher was not allowed to give the students information which they did not need in order to solve the problem.

Teachers did not demonstrate or make explicit any initial expertise in teaching general research activities (Table 2: c). Although, one can expect that they had some expertise, because performing research activities is often part of the conventional curriculum. They were not aware that it was part of the context-based chemistry curriculum at this stage of the programme.

During the preparation phase, all teachers acquired an awareness how the content could be integrated within specific activities determined by the context (Table 2: a). They focused on the specific activities of problem-solving in product development. Sue, Chad and Rich acquired new expertise, which was additional to the initial expertise, with regard to teaching on a need-to-know basis (Table 2: b). Other teachers did not reveal newly acquired expertise with regard to teaching on a need-to-know basis. During the preparation phase, all teachers except for Chad showed to be aware that, they needed to teach general research activities to help students to solve the problem (Table 2: c). During the programme, all the teachers acquired some new expertise in the abilities a-c, and x (Table 2). This expertise was considered as shared expertise in (i) setting the context in class.

To illustrate these findings, the results of Sue are described. During the third meeting, Sue shared that she was not able to adapt the activities in the unit because the intended effects on students of particular activities were not clear to her. She showed that she was able to apply her understandings about student difficulties to identify moments or activities that might cause difficulties during instruction. She planned to pay more attention in class to teach general research activities. At the time of the interview, she made explicit to understand the sequence of activities in the unit as a product development procedure. She also demonstrated being able to determine students' expected learning difficulties in carrying out these procedures, and how she could help them.

This indicated that Sue had acquired expertise in planning and teaching the activities as intended in the design of the unit. She had acquired expertise in teaching the problem-solving procedure and the related activities in the unit. She demonstrated her expertise in teaching general research activities. About teaching on a need-to-know basis, she mentioned in the interview that she could not provide the students with a solution for the problem, because she indicated that there were more solutions to the problem. From her point of view, she acquired some more understanding about what was intended to be achieved by teaching on a need-to-know basis. In addition, she put forward initial ideas about how to organize project teams in class.

All the teachers focused on organizing and managing project teams in their classes (Table 2: x). They considered this to be a major stressor when preparing the unit. They also expressed feelings of insecurity. In the discussions during meeting one, two and three, Chad emphasized that he had problems in managing the project teams. As he had some previous experience of teaching this unit, the other teachers considered this to be the most difficult part of teaching the unit and therefore tried to prepare thoroughly. They considered learning about how to work together in project teams to be one of the main learning effects for students. In their lesson plans teachers revealed the ways in which they were planning to organize the project teams in their own school situations. The teachers paid a lot of attention to ensure that the students were motivated and would gain insight into why they had to learn the content involved.

During instruction and reflection, the newly acquired expertise in ability c was expanded by all teachers during instruction and reflection. Only Sue expanded the newly acquired expertise in ability a and b.

Tony and Rich demonstrated and shared their expertise in the mid-way evaluation meeting with regard to teaching problem-solving procedures in product development. When teaching the unit in a previous occasion, Tony noticed that, after skipping one of the activities, the students did not pass the final assessment. He reported in his log that this activity was crucial for students to achieve the intended learning effects and that they needed much guidance to carry out this activity. In the discussion about creating the lesson plans, Rich stated that it was better for the students to first develop a product intuitively, before starting to search the literature for more information about the problem. When Tony and Rich shared this in the discussion, the other teachers replied that they already knew this before the instruction. Therefore this expansion of the expertise is considered to be more personal, and is not part of the newly shared expertise.

In addition, Sue did not make explicit or demonstrate her expertise in teaching the unit in the meetings during instruction and reflection. However, other data sources gave some insight in Sue's expanded expertise. This means that she did not make her personal expanded expertise explicit and share this among teachers. Sue's second recorded lesson involved students in carrying out experiments, developing different composite materials and testing the strength of these materials. She said that during the lesson she had noticed that students had difficulties to perform these activities and made sure that students learned to carry out these activities. In addition, in her log Sue enumerated her ideas about how to improve her teaching of general research activities. In the recorded lesson Sue demonstrated a expertise in teaching general research activities, such as designing experiments, using lab equipment, formulating research questions and writing research reports and organizing project teams in class (Table 2: c, x). She reported that students needed to learn how to perform general research activities first, instead of learning them on a need-to-know basis by performing problem-solving procedures in different context-settings. This indicated that she expanded her expertise by understanding when and where to apply the need-to-know approach in teaching problem solving procedures and general research activities (Table 2: a, b, c).

Teachers' development in performing the new teachers' role

Teachers' development in (ii) performing the new teacher's role involved the acquisition and expansion of expertise in the abilities d-f (Table 2). In her initial lesson plan, Sue demonstrated to have an initial expertise involving making students problem owners and organizing student-centred instructions in class. Besides Sue, other teachers did not demonstrate or make explicit that they had an initial expertise in helping the students to experience ownership of the problem of developing a product with the desired properties (Table 2: d). All teachers were initially aware that the balance between student-centred and teacher-centred instruction was different compared to their usual practice (Table 2: e). In contrary of the expertise in the ability f.

During the preparation phase, the teachers were concerned about the initial capacities and opinions of the students. According to the teachers, the students should have been more challenged than they were. However, the teachers were not convinced that the students would be able to achieve the intended student effects. Teachers wanted to ensure that the students were engaged in solving the problem (Table 2: d). They focused mainly on the preconditions necessary to ensure that the students experienced ownership for solving the problem. During the preparation phase, the teachers became aware that the balance of student- and teacher centred instruction changed (Table 2: e) and they had a role in structuring and ordering new knowledge for the students (Table 2: f).

The teachers focused on how to guide the students instead of plenary teaching. Tony, Rich and Chad put themselves in the role of assessor by giving the students marks for every activity. Tony recalled that this had been a difficulty in prior experiences, and shared that he planned to check the students more often, because the students needed more guidance compared to teacher-centred instruction. In the interview, Chad said that he adapted the unit so that the students were able to carry out the activities without teacher involvement. Rose and Tina said that they put themselves in the role of facilitator for students to perform the activities to solve the problem, so they could have a feeling of ownership about the task.

Sue demonstrated detailed ideas about performing her role towards the students. She thought about how to motivate the students while maintaining an overview and monitoring the learning process 'from a distance' as a senior member of the project team without interfering in the process as a teacher too much. Karin anticipated that students would experience certain difficulties in performing the activities described in the unit. In relation to these difficulties, she planned to organize the balance between teacher-centred and student-centred instruction during the lessons, and monitoring and evaluating the learning process of the students were going through. Sue made it explicit that she had acquired a expertise in how to structure and facilitate the anchoring of new knowledge onto the initial knowledge of students by having plenary sessions in every lesson and by students making summaries and logs after every lesson.

However, the teachers focused mainly on maintaining an overview of the problem -solving activities and relating the outcomes of the activities to a possible solution. Like Sue, Rich thought that he would give the students summaries of the content and extra assignments, in order to achieve the intended learning effects and to practise for the final assessment. In addition, like Sue, Tina said in the interview that she would give the students an overview of the activities at the beginning of each lesson and relate these activities to the intended learning effects. All teachers acquired expertise in the abilities d-f. This expertise was considered as shared expertise in performing the new teachers' role.

Teachers expanded the newly acquired expertise in ability f. To illustrate, during the instruction phase Tony reported in his logs that the teacher needed to keep an overview of the activities which were related to a possible problem solution. In the reflection meeting, all the teachers reported that they wanted to pay more attention to this issue the next time they taught the unit.

Only Sue expanded the newly acquired expertise in balancing between student-centred and teacher-centred instruction (Table 2: e). Although during preparation, Sue reported that learning to work in project teams was an important learning effect for students. In the reflection meeting she explained that she already had the expertise of managing project teams, but she became more aware of applying it when teaching this context-based chemistry unit. Sue made explicit that she had expanded her expertise in organizing a balance between student-centred and teacher -centred instruction.

In the final reflection meeting, Tony said he still had trouble in motivating the students and in performing the role of senior member of the project team (Table 2: d, e). Except for Sue, Tony and other teachers did not demonstrate or make explicit any expansion of their expertise with regard to giving the students a feeling of ownership or in organizing a flexible balance between student- and teacher centred instruction.

Teachers' development in teaching the new content

Teachers' development in (iii) teaching the new content of macro-micro thinking in structure-property relations involved the acquisition and expansion of expertise in the category of ability g (Table 2). Sue, Tony and Chad associated context-based chemistry education with the content of macro–micro thinking. They stated that the students needed to explain properties with structures on meso-levels. Students should use the micro-level only when it is necessary to solve the problem. Tina gave an example of a lesson in which the students needed to zoom in on the structure of a food product in order to explain its properties. As described earlier, Sue referred to a problem of an iron drawbridge (Figure 3: structure on macro-level) that did not close when the weather outside was hot. She wrote that she explained to the students that iron atoms (Figure 3: structure on micro-level) move faster (Figure 3: property on micro-level) when it is hot outside, causing dilatation of the construction (Figure 3: property on macro-level). The lesson plans gave insight into how Sue used examples in her instructions which implicitly involved macro–micro thinking, and that she understood what macro–micro thinking involved. However, she taught macro–micro thinking by reasoning directly from the macro-level to the micro-level according to the conventional curriculum. She did not demonstrate how to teach macro–micro thinking using structures on meso-levels to explain the dilatation of the iron construction of the bridge.

During the preparation phase, the teachers expressed no additional details of their expertise with regard to how to teach this content of macro-meso-micro thinking to the students. During these meetings, the teachers made it explicit that they were aware that students had to learn macro–meso-micro thinking as intended. For example, in the interview, Sue and Tina demonstrated an awareness that macro–meso-micro thinking was an intended learning effect, although they focused on students naming the properties.

In the discussions and logs during the instruction and reflection phase, the teachers only repeated what the coach mentioned and what they already shared as part of their initial expertise: macro–micro thinking was about structure–property relations and zooming in on the structure of a material. None of the teachers demonstrated or made it explicit that they had acquired or expanded their expertise with regard to teaching macro–micro thinking. Teachers still repeated what they had already expressed beforehand during preparation. When reflecting, the teachers reported that they had no time to focus on achieving the effects of the content of macro–micro thinking, because organizing and managing the project teams took too much effort. No additional shared expertise was developed in teaching the new content of macro-micro thinking in structure-property relations.

Teachers' emotions during the programme

The teachers' emotions, which could have caused the poor expansion of teachers' domain-specific expertise during instruction and reflection were also analysed and described. In the first meeting, teachers reported being concerned that the level of chemistry education for students should be higher. In addition, the teachers showed their concerns that the students at the end of the school year should be more interested and motivated to learn chemistry, even if they would not be continuing their education in that subject over the following year. They reported being curious about what context-based chemistry education would entail, and the effects it would have in class. The teachers shared their feelings of insecurity with regard to achieving the intended effects on students. However, the teachers thought that this specific unit would ensure that the level of chemistry education would increase, and that this unit would help to motivate students to work and learn.

Although the teachers did not explicitly say that they were insecure about their own abilities to teach the unit in class, they expressed this in non-verbal ways in the meetings. In order to cope with their insecurities and the stress in teaching a context-based chemistry unit, the teachers together focused on adapting the unit, so that it could 'work'. The teachers noticed that they needed to adapt the activities in the unit, to be able to instruct the unit in their own classes. However, they discussed that they were not able to adapt the content or the activities of the unit to their own school situations. The adaptations to the unit demonstrated that, in contrary to their planned adaptations, they only adapted the layout of the text in the unit. However, they explicitly revealed a significant understanding of the difficulties which the students could experience in reading and understanding the texts, tables and figures in the unit, and adapted the lay-out where they thought it was necessary. In addition, they made lesson plans, to ensure that they would not lose control in class. After preparation, the teachers expressed the feeling that they were well-prepared and they showed confidence in teaching the unit in their own school situations.

The teachers expressed that their confidence dropped, when they instructed the unit in their schools. They showed coping strategies of doubting the quality of the unit and the abilities of the students, especially in the first lessons. Managing the project teams was still difficult for the teachers and this took a great deal of effort. In addition, the teachers faced the insecurity of 'doing something new' with the students. They expressed that this made them feeling insecure as well. In the lessons, the teachers were mostly concerned about whether the students were doing what they were supposed to do. When the students did not perform these activities the teachers 'blamed' this on the fact that the content was too difficult for them, or that they were not motivated at the end of the school year. They also felt insecure when they did not know 'the right answers', when the students asked questions about the activities. Because the teachers were 'surviving' instead of learning, this may have hindered the expansion of the newly acquired expertise. Although the teachers did not achieve all the effects on students they described during preparation of the unit, they were satisfied with their achievements and still perceived some positive aspects of the curriculum innovation.

Discussion

This study aimed to describe the personal and shared domain-specific expertise that teachers develop when they participate in a professional development programme, in which they teach an exemplary context-based chemistry unit in a collaborative setting. The professional development programme intended the simultaneous development of all three aspects of new expertise with respect to (i) context-setting, (ii) the new teachers' role and (iii) the new content of materials science using macro-micro thinking in structure-property relations. The results showed that the teachers had acquired newly shared domain-specific expertise in terms of setting the context and performing the new teacher's role. However, the teachers had only shared their initial expertise, but did not develop newly shared expertise in terms of teaching the content about macro–micro thinking in structure-property relations.

This study shows that a professional development programme in which teachers prepare and instruct a context-based chemistry unit, and reflect upon this instruction, not necessarily facilitates the simultaneous development of teachers' expertise in the three aspects of context-based education. An in-depth understanding is provided into what development in new domain-specific expertise is facilitated when teachers participate in professional development programmes, and what specific difficulties can be expected in developing domain-specific expertise in collaborative settings as described in the literature (Butler et al., 2004; George and Lubben, 2002; Whitcomb et al., 2009).

Considering the complex interplay between the three new aspects of the intended domain-specific expertise, it is difficult to facilitate the integrated development of these three aspects of (i) context-setting, (ii) teacher’s role and (iii) content. As Pilot and Bulte (2006) discussed in relation to context-based curricula, it is essential to pay attention to all three aspects in the teachers’ professional development. Through the interplay between the teachers’ shared initial expertise and their personal experiences in a specific domain (Wenger, 2000), the development of newly shared domain-specific expertise can take place (Brodbeck and Greitemeyer, 2000; Verloop et al., 2001). However, this study shows that in this interplay teachers do not necessarily develop newly shared expertise in all three aspects. Potential reasons for the lack of expertise development in teaching the new content will be discussed. This will result in recommendations for further research to improve and adapt the professional development programmes based on the framework of Stolk (Stolk et al., 2012).

Firstly, the teachers’ emotions and feelings of stress could have caused the (lack of) acquiring and expansion of teachers’ expertise in teaching the new content. The feelings of individual teachers can influence the shared development in a positive way, but also in a negative way (Carlyle and Woods, 2002). Hingant and Albe (2010) and Tuvi-Arad and Blonder (2010) have shown that a professional development programme on the new content of nanotechnology has led to new teachers’ expertise of the domain. However, the authors also report the teachers’ insecurity on how to teach such new content (Hingant and Albe, 2010; Tuvi-Arad and Blonder, 2010).

Secondly, in this study the social interaction between members within a collaborative setting influenced the groups atmosphere (Kelchtermans, 2005). The difficulties in teachers’ development might specifically occur when they experience an overload in what they need to do and achieve in an entirely new situation. Then, the interplay between initial expertise and new experience results in a sharing of personal difficulties and stressors, which could hinder the acquisition of the new expertise when preparing for a new teaching approach. In addition, the experience of status and hierarchy among the group members could have hindered an open learning attitude of the group (Forsyth, 2010), as for example took place in the setting of this study in relation to organizing and managing project teams in class.

This study involved the acquisition of new content on macro-‘meso’-micro thinking. In the programme, teachers became aware at a very late moment that the teaching of this unit indeed implied new content. As the expertise regarding the content is a prerequisite for experience and therefore development (Van Driel, Verloop and de Vos, 1998), insufficient preparation on new content hindered the teachers’ development during the instruction phase. Consequently the reflection on their actions and the achieved student effects was of low quality. They did ‘survive’ and manage to teach the entire unit in class and even became positive and motivated to further expand their expertise on the content of macro–micro thinking. However, the quality of reflection on teaching this new content could have been higher if teachers had been better prepared for teaching the new content.

The overload and the resulting feeling of stress that teachers might have experienced during instruction can be avoided when a programme provides a sufficient problem analysis prior to teaching. Several researchers report that such a problem analysis can be successful when teachers become aware of what the similarities and differences between teaching in the conventional and new curriculum are, in order to get a clear image of what new expertise they need to develop during the programme (Handelzalts, 2009; Stolk et al., 2011; Stolk et al., 2012; Voogt et al., 2011). Sufficient preparation has occurred when teachers experience what aspects are new and can avoid feelings of insecurity and a decrease in their self-efficacy (Brown, Ralph and Brember, 2002; Evers, Brouwers and Tomic, 2002; Kokkinos, 2007; Thompson, 2005).

This leads to the recommendation that, in a professional development programme, a good balance needs to be established between a focus on new content and the other aspects. This avoids teachers’ feelings of stress and also avoids that all they are doing in class is ‘surviving’ when teaching a new unit. This may influence the expansion of their expertise in a negative way. It can also lead to the recommendation that , teachers become facilitated in the preparation phase in order to conduct a sufficient problem analysis in teaching the new content when designing a professional development programme.

This study provided new insights into the expertise development of teachers in collaborative settings. However, some limitations of the findings should be discussed. It was not in focus of this study to take the interaction between teachers and teaching materials into account. However, it is found that the design of the context-based chemistry unit has a great influence on teachers’ implementation of context-based education in class (Vos, Taconis, Jochems and Pilot, 2010; Vos, Taconis, Jochems and Pilot, 2011). In addition, since this study involved only one small group of teachers, no attempts are made to generalize the findings of this study. This study is limited to an analysis of the shared expertise that these teachers developed, based on the descriptions of teachers' personal development. In addition, teachers' development of domain-specific expertise was not independently assessed, for example by tests, but was mainly based on an analysis of the teachers' performance. Besides, this study did not involve data on student learning and achievements during instruction, because this was not the focus of study. Information about the students' achievements was only retrieved from teachers' perceptions about their classroom practice.

This study contributes to an understanding of how the teachers expertise develops in a professional development programme when implementing an ambitious new context-based curriculum. The development of new expertise in teachers has been mapped to show what can be achieved, including the factors hindering the development. Major challenges involve the understanding and effective use of group dynamics in a collaborative setting in terms of professional development, effective preparation regarding the differences between old and new content, and the balancing of the development of several aspects of the new domain-specific expertise when giving shape to an appropriate programme .

Further research needs to provide more understanding of the influence of the group dynamics and social interaction on teachers' feelings of stress of experiencing a changing domain and practice, and their development of domain-specific expertise, when they participate in a collaborative setting in a professional development programme. In addition, more research need to be conducted to investigate how to improve the professional development programme to facilitate teachers' development of expertise in all three new aspects of context-based chemistry education, especially in teaching the new content of macro-micro thinking in structure-property relations.

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Appendix

Table 1 The professional development programme

Phase	Functions	Activities	Data collection
Initial	a. Connect to teachers' views on context-based education b. Reveal 'useful' teachers' initial domain-specific expertise	• Assignment to make or provide a mind-map (associations), lesson plan and student assessment from their regular programme, related to their initial views of context-based education (function a, b)	-Mind map -Lesson plan -Student assessment
Preparation of the unit	c. Let teachers discover differences and similarities among their views on context -based education and the context-based unit d. Let teachers explore strategies for teaching the context-based unit, give examples, and present conditions for use e. Provide the opportunity for teachers to define their learning goals	**1. Introduction** • Teachers getting acquainted with each other and share what they reported in the initial assignment (function a, b) • The coach presents the unit that is being taught and shares his earlier experiences when coaching teachers to teach the unit (function c) *Homework:* • Study the unit, student activities and effects in detail, to teach in teachers' own school situation (function d) • Thinking of 'successful events' in teachers experience when teaching the conventional curriculum (function c, d)	-Video recordings
		2. Definition of Teacher Learning Goals • Teachers share their 'successful events' and report them on a joint poster (function b, d) • Teachers following the four-step approach to define their learning goals (function d, e): 1. Define intended student effects 2. Relate intended student activities to the effects 3. Explore teachers' actions to achieve the intended student effects 4. Define teachers' learning goals in accordance • *Homework:* • Adapting the unit to instruct in teachers' own school situation taking teachers' learning goals and successful events into account (function d, h)	-Video recordings
		3. Planning to instruct the unit • Reporting and discussing the adaptations of the unit by following a collaborative learning approaches (function c, d) • The coach introduces various collaborative learning approaches that could be applied when instructing the unit (function c, d) *Homework:* • Adapting the unit further to instruct in teachers' own school situation (function d, h)	-Video recordings

Preparation of the unit		**4. Planning to instruct the unit** • Elaborating in a discussion on the teaching actions to achieve the intended student effects and teachers’ learning goals (function d, e) *Homework:* • Making lesson plans including teachers’ learning goals and a mid-term student assessment (function d, e, h)	-Video recordings
		5. Planning to instruct the unit • Reporting and discussing the lesson plans and student assessments (function d, e) *Homework:* • Finishing up the definitive versions of the unit, lesson plans and students' assessments (function d, e, h)	-Video recordings -Adapted unit -Lesson plans (including teachers’ learning goals) -Student assessments
Instruction of the unit	f. Provide the opportunity to apply the domain-specific expertise in practice	Instructing first part of the unit in teachers’ own school situation (function f)	-Video recordings of one lesson -Interview based on video recall -Mind map -Teachers’ log
		6. Mid-term evaluation and reflection • Sharing experiences and discussing the instruction of the lessons, lesson plans and adapted unit based on the outcomes of the mid-term student assessment (function g, h) • Sharing and discussing individual problems experienced during instruction (function g) • Preparing the lesson plans and the final student assessment for the second part of the instruction (function d, h) *Homework:* • Developing the final lesson plans and student assessment (function d, h)	-Video recordings
		Instructing second part of the unit in teachers’ own school situation (function f)	-Video recordings of one lesson -Teachers’ log

Table 1 (continued)

Reflection upon instruction	g. Give teachers the opportunity to reflect on their teaching and learning experiences h. Examine teachers' development by creating the opportunity for teachers to produce a product i. Evaluate teachers' development	**7. Evaluation and Reflection** • Expressing experiences, emotions and feeling during instructing the unit (function i) • Sharing and discussing the intended student activities and student effects of the unit, the problems experienced during instruction, teachers' development, etc. (function g, i)	-Video recordings
		8. Reflection and Incorporation • Reflecting on teaching the unit, participation in the programme, incorporating the expanded expertise by adapting strategies for teaching the unit on a subsequent occasion (function f, g, h, i)	-Mind map -Video recordings -Teachers' reflection report

Table 1 (continued)

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Chapter 1 Design issues	The collaborative setting	The sequence of activities within the framework	The development of intended domain-specific expertise
Explorative study			**Chapter 2** Determining the intended domain-specific expertise
First case study	**Chapter 4** Exploring patterns in group dynamics that influence teachers' development of domain-specific expertise		**Chapter 3** Describing the domain-specific expertise that teachers develop during the programme
Second case study		**Chapter 5** Planning a sequence of activities within the framework to support teachers' development	
Chapter 6 Understandings for designing	Strategies in composing and coordinating collaborative settings to support teachers' development	Strategies in planning the activities to support teachers' development	Description of the intended domain-specific expertise

Chapter 4

The Professional Development of Teachers from the Perspective of Group Dynamics[1]

Abstract

This study aims to identify patterns in the group dynamics of collaborating teachers that influence the development of domain-specific expertise in a professional development programme involving teaching a context-based unit. A case study was conducted in which six teachers taught a unit in a collaborative setting. Data analysis, following a qualitative inner-case approach, resulted in the identification of three patterns in group dynamics regarding teachers' engagement, the roles of group members and the coordination of coaching, which influenced social interaction among the group members and as such influenced the development of domain-specific expertise. The productive use of these patterns to enhance teachers' development of domain-specific expertise and the implications of these results for designing a professional development programme to support teachers in curriculum innovations are discussed in detail here.

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[1] This chapter is submitted as:

Dolfing, R., Bulte A.M.W., Pilot, A., Vermunt, J.D. (*submitted*). The Professional Development of Teachers from the Perspective of Group Dynamics.

Introduction

In order to foster the professional development of teachers and implement educational innovations, organizing collaborative settings, such as Communities of Practice, is a promising strategy (Brown and Duguid, 1991; Butler, Lauscher, Jarvis-Selinger and Beckingham, 2004; Swan, Scarbrough and Robertson, 2002; Vescio, Ross and Adams, 2008). Based on the notion that teacher learning is enhanced by collaboration, this is a frequently used strategy in teacher development (Brouwer, Brekelmans, Nieuwenhuis and Simons, 2012; Vescio et al., 2008), educational innovation (Bakkenes, Vermunt and Wubbels, 2010), school improvement (Harris and Jones, 2010) and the teaching and development of curriculum units (George and Lubben, 2002; Whitcomb, Borko and Liston, 2009).

From the perspective of group dynamics, collaboration can be understood as a collection of specific patterns which individuals use in a variety of situations (Opfer and Pedder, 2011). Group dynamics involve an understanding of the characteristics of and interactions among individual teachers and their motivations and engagement with the purpose of the group (Forsyth, 2010). When these characteristics, interactions and engagements come together, the participating teachers are more likely to share experiences, discuss problems, create strategies and arrive at solutions to teaching problems together.

To support teachers in curriculum innovations in terms of context-based education, professional development programmes are organized in which teachers participate in collaborative settings to teach exemplar units and develop domain-specific expertise (Coenders, 2010; De Putter-Smits, Taconis, Jochems and Van Driel, 2012; Stolk, De Jong, Bulte and Pilot, 2012). However, in such a collaborative setting, teachers do not necessarily develop the intended domain-specific expertise, especially when teaching new content (Chapter 3; Dolfing, de Jong, Bulte, Pilot and Vermunt, 2011). Group dynamics within such collaborative settings might have an influence on teacher development. Therefore, to explain and understand teachers' learning in such collaborative settings, empirical research is necessary to understand how group dynamics can influence teachers' development of domain-specific expertise (Borko, 2004; Breu and Hemingway, 2002). This provides more insight into why and how collaboration enhances teacher learning (Vescio et al., 2008).

The scope of this research involves supporting teachers in developing domain-specific expertise by teaching a context-based unit in a collaborative setting. The aim of this study is to identify patterns in group dynamics that influence teachers' development of domain-specific expertise. This provides more insight into why collaboration enhances teacher learning and how to improve professional development programmes in terms of curriculum innovations.

Patterns in group dynamics

When adopting the General System Theory (Von Bertalanffy, 1968), a group of teachers can be considered as an open system with permeable boundaries, consisting of interconnected interdependent subsystems (group members) (Decuyper, Dochy and Van den Bossche, 2010). The system consists of the group structure and the group processes of social interaction among the teachers (Figure 1). Establishing and maintaining a functional group structure is required in order for the group to perform its task of teaching the context-based unit, and as such to develop domain-specific expertise. Although such a group of collaborating teachers is formally organized, the structure is much less predefined and the group roles, norms and communication patterns must be established by self-organization (Ashby, 1962), during processes of group formation and social interaction (Breu and Hemingway, 2002; Grossman, Wineburg and Woolworth, 2000).

The group processes of social interactions among the group members are considered to be the mediator between group structure and the development of domain-specific expertise (Figure 1) (Mathieu, Maynard, Rapp and Gilson, 2008). Social interactions can be recognized as dynamic, and are not static and constant (Stempfle, Hübner and Badke-Schaub, 2001). In terms of social interaction, patterns can be revealed (Kelso, 1995). Such collections of patterns imply generative underlying mechanisms, and this may explain why and how collaboration enhances or stagnates teachers' development of domain-specific expertise. These patterns can be analysed from observations of social interactions in the form of series or sequences of similar events in time (Dooley and Ven, 1999). Describing patterns in group dynamics involves that influence teachers' development of domain-specific expertise, that factors in the structure of the group and social interaction within the group are identified and described that enhance of stagnates teachers' development in a collaborative setting.

Factors in the group structure influence social interaction among group members, and so affect the development of domain-specific expertise (Forsyth, 2010). These factors involve, for example, status, roles of and hierarchy among the group members, the coordination and leadership of the coach, and teachers' motivation to share expertise among the group members, teachers' engagement towards the purpose of the group, group composition including age, gender and the prior experience of group members and the common rules and norms in communication in the group (Akkerman, Petter and De Laat, 2008; Breu and Hemingway, 2002; Brodbeck and Greitemeyer, 2000; Forsyth, 2010; Wilson, Ludwig-Hardman, Thornam and Dunlap, 2004). To explain teachers' development of domain-specific expertise when participating in a collaborative setting in this study, three categories of factors seem to be important to consider. These categories are elaborated in the next few paragraphs.

The first category involves teachers' engagement into the purpose of the group and into participating in the activities of the professional development programme and their motivation to learn and to share expertise and experiences. Engagement in learning activities and motivation to learn are constructs that are related (Naquin and Holton, 2001). Motivation to learn, motivation to transfer and evaluate previous developed experiences have a direct effect on teachers' engagement in professional development activities. Teachers' motivation to learn can be defined as their desire to develop the intended domain-specific expertise during professional development activities. The learning of teachers improves when it is focused on ways in which teachers can share, discuss and develop their expertise (Breu and Hemingway, 2002).

The second category, which involves factors of leadership and coordination of coaching, can have a strong effect on the establishment of roles within the group (Day, Gronn and Salas, 2004). In the professional development programmes described in this study, collaborative settings are usually organized formally and the group, as such, is guided by a coach. The coach plays a special role in the coordination of the group, and may have a great influence on the social interaction between the teachers and consequently on the development of domain-specific expertise.

The challenge of the coach in coordinating the group lies mostly in creating group ownership of the direction of group activity, creating a favourable disposition and a positive attitude towards the learning experience, and of creating an atmosphere of respect and interdependence by sharing experiences and guidelines for group discussions (Brouwer et al., 2012; Wlodkowski, 2003). The coach can stimulate the group to discuss what is meaningful by engaging them in conversations about needs and objectives and can allow the group to discover both the rewards and the responsibilities of being a group member (Breu and Hemingway, 2002). This enhances

Group Dynamics involves:
The structure of the group and social interaction among participants

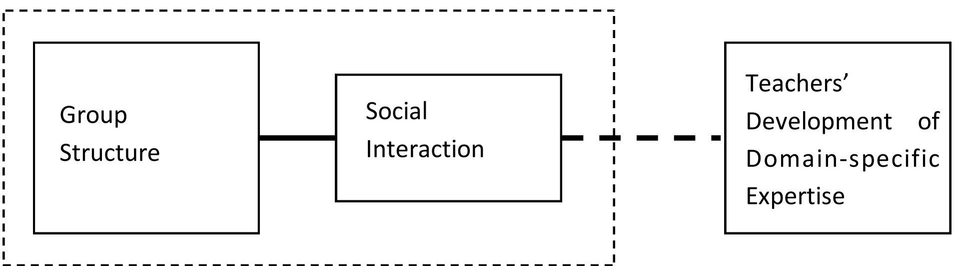

Figure 1 Patterns in group dynamics that influence teachers' development

meaningful activity but also stimulates a primary commitment by the members towards each other (Akkerman et al., 2008).

The third category concerns the group composition, status, roles and hierarchy of the group members. Humans live in groups with organized systems of power relations. Group members accept influence from others because such behavioural responses are adaptive. So long as authority is motivated to advance the interests of the group, then those who are lower in the status hierarchy tend to do as they are told by those with higher status (Kessler and Cohrs, 2008). As the processes in a group are dynamic, the roles of members tend to develop during the task performance of the group (Sjøvold, 2007) and this can influence intergroup behaviour, social interaction and perceptions within a group (Sachdev and Bourhis, 1991).

This study focuses on identifying and describing patterns in group dynamics, in terms of factors in the group structure and social interaction among group members that influence and explains teachers' development of domain-specific expertise in a collaborative setting. Based on (a series of) similar events during group meetings, the patterns can be identified and described within the categories of (I) teachers' engagement with the purpose of and motivations of sharing expertise in the group, (II) the coordination and leadership of the coach, and (III) the roles, status of and hierarchy among the group members.

The curriculum innovation and intended domain-specific expertise

Implementing context-based curricula is an international trend in science education. Examples of such curricula are *the Salters Approach* in the United Kingdom (Bennett and Lubben, 2006), *Chemie im Kontext* in Germany (Parchmann et al., 2006), *ChemCom: Chemistry in the Community* in the USA (Schwartz, 2006) and Industrial Chemistry in Israel (Hofstein and Kesner, 2006). This study is situated within the curriculum innovation of context-based education in the Netherlands (Meijer, Bulte and Pilot, 2009; Prins, Bulte, van Driel and Pilot, 2008; Van der Zande, Waarlo, Brekelmans, Akkerman and Vermunt, 2010; Verhoeff, Waarlo and Boersma, 2008; Vollebregt, 1998; Westbroek, 2005). This curriculum innovation involves innovative context-based units being designed. The redesigning of science curricula in terms of innovative units implies that a new domain-specific content being developed that is not part of the teachers' expertise (Chapter 2; Dolfing, Bulte, Pilot and Vermunt, 2012). In addition, it involves a new role for the teacher in relation to the students. Consequently the teachers' regular expertise was not sufficient and needed considerable extension (Van den Akker, 1999; Vos, Taconis, Jochems and Pilot, 2011).

In exemplar units of this curriculum innovation, the new content and teacher's roles towards the students are determined by the context-setting (Meijer et al., 2009; Prins, Bulte and Pilot, 2011; Westbroek, Klaassen, Bulte and Pilot, 2010). The 'context' in context-based education is conceived of as the setting of a social activity, within which the students' behaviour and mental experiences are situated, using the relationship of situated background knowledge and specific language (Gilbert, 2006; Gilbert, Bulte and Pilot, 2011). In addition, the 'context' must provide the basis for the development of coherent 'mental maps' of the content, so that students perceive learning of the content as being relevant and feel a sense of ownership over what is to be learned. In this particular curriculum innovation, the context-setting involves project teams, consisting of students and teachers, being assigned to solve a problem in product development. Students need the new content as a tool to solve this problem. The teacher performs the role of the senior member of the project team and guides the students in product development procedures.

Expertise has been defined as 'the ability to perform successfully in a specific domain' (Ericsson, Charness, Feltovich and Hoffman, 2006). Following this definition, the intended development of teachers' domain-specific expertise involves (i) the ability to set a context in class, (ii) to perform the new teacher's role and, as well, (iii) to teach the new content (Dolfing et al., 2012). In this way teachers influence the students' learning in achieve the intended effects of the curriculum innovation. These effects involve not only student learning outcomes specific for this innovation of context-based education, but also more general outcomes in both the short and long term, such as enhancing student interest and increasing the level of education in secondary schools (Ryder and Banner, 2011).

For a successful implementation of such a curriculum innovation, teachers need support to develop the kind of domain-specific expertise that is required for this tremendous change in their practices in comparison to teaching the conventional curriculum. As such, teachers participate in professional development programmes, in which, guided by a coach, they collaboratively design, adapt and teach context-based units and exemplars for the curriculum innovation (Coenders, 2010; De Putter-Smits et al., 2012; Handelzalts, 2009; Stolk, De Jong, Bulte and Pilot, 2011; Stolk et al., 2012; Voogt et al., 2011). In such a professional development programme, it is intended that teachers develop domain-specific expertise in pedagogy, subject matter and content, class management and so forth, which is required to teach a context-based unit. Also, such professional development can be used to enhance teachers' beliefs that they can succeed in implementing innovations to their own situation (Abrami, Poulsen and Chambers, 2004).

However, in a previous case study, it was found that teachers participating in such a programme only partly developed the intended domain-specific expertise to teach a context-based unit (Dolfing et al., 2011). The results showed that the teachers developed their expertise in (i) setting the context in terms of (ii) performing their new roles as teachers, but did not develop new expertise in (iii), teaching the new content. In the programme, teachers prepared the unit collaboratively for instruction, then instructed the unit individually in their own classes, then reflected collaboratively upon this instruction. During the programme, the teachers' development was hindered at the beginning of instruction by insufficient preparation for teaching the new content. In this study the perspective of group dynamics is used to explain and understand teachers' development, especially the lack of development in teaching the new content.

Scope and Research Question

The scope of this research includes explaining and understanding teachers' development of domain-specific expertise in teaching a context-based unit in a collaborative setting from the perspective of group dynamics. This study aims to identify patterns in group dynamics, concerning (I) teachers' engagement with the purpose of the group and motivations towards sharing expertise, (II) the coordination and leadership of the coach, and (III) roles, status of and hierarchy among the group members that influence the development of domain-specific expertise in terms of (i) setting the context in class, (ii) performing the new teacher's role, and (iii) teaching the new content of context-based units. This provides more insight into why and how collaboration enhances teacher learning and how to improve professional development programmes, in which teachers teach context-based units in a collaborative setting in order to develop the intended domain-specific expertise. The research question was then:

What patterns in the group dynamics of collaborating teachers can be identified that influence teachers' development of the domain-specific expertise that is required for teaching a context-based unit?

Method

In order to identify the patterns in group dynamics that influence and explain teachers' development of domain-specific expertise, the data collected during the case study described in Chapter 3 was further analysed. In this case study (Creswell, 2007), six teachers, guided by an experienced coach, taught a context-based unit in a collaborative setting. In this section, first the procedure in this collaborative setting was described, followed by a description of the participants, materials, data collected and then the analysis.

Procedure

Teachers were motivated to become group members by referring to their personal interests in curriculum innovation, to problems they expressed in their school situation that could be solved by teaching the context-based units, the chance to work together and share experiences with teachers from other schools. In addition they were motivated to collaboratively contribute to and give advice about curriculum innovations by experience the attainability of teaching these kind of units in their own school situation. Remuneration was provided and intensive coaching and professional development was offered to prepare for the upcoming curriculum innovation.

The teachers were assigned to the task of teaching a context-based unit that involved new domain-specific expertise in (i) setting a context in class, (ii) performing the new teacher's role and (iii) teaching the new content. In teaching this unit in a collaborative setting, it was intended to create group ownership and engage the teachers in discussions about which forms of domain-specific expertise they needed to develop to teach the context-based unit and which objectives and effects on students they needed to achieve.

Teaching the unit involved collaborative preparation, in teachers' own classes and collaboratively sharing and reflecting upon their experiences. Teachers interacted in discussions, coordinated by the coach, about teaching dilemmas that were driven by the teachers' needs and established roles, their relationships and mutual objectives. In these interactions, teachers were expected to develop the intended domain-specific expertise, through the interplay between personal experiences and the initial (shared) expertise of the members.

The preparation involved five meetings of two hours each over three months. Preparation of the unit involved adapting the unit to the individual school situation, designing lesson plans, conducting student assessments and defining teachers' own learning goals in order during instruction in the unit.

The instruction took approximately 10-12 regular lessons and teachers discussed their teaching experiences in a midway evaluation meeting and reflected upon their experiences in a weekly log. Based on their discussions in the midway meeting, the teachers decided whether or not they needed to change their teaching strategies in the second part of the instruction.

After the instruction, the teachers and coach reflected in two meetings together on their experiences of adapting the unit and on their teaching strategies for the next time they would teach the unit. The first meeting occurred directly after the instruction and the second meeting was planned three months later.

The coach coordinated the teachers by leading their discussions and supporting them in understanding what learning effects the students needed to achieve and what actions they could take to achieve these effects in their own school situation. This involved the coach sharing his own experiences and/or giving them additional literature about various teaching strategies and pedagogical approaches that they could use. He did not tell the teachers how to teach context-based units as the teachers were already considered to be experts in their own school situations. The researcher (author of this thesis) was present at the meetings and was responsible for collecting data, so inevitably she influenced the discussions.

Participants

The teachers in this group had two, three, five, seven, nine, and 35 years of experience in teaching in secondary schools. They came from four different schools. Two pairs of teachers came from the same school. One pair of the teachers had taught a previous version of the particular context-based chemistry unit on two previous occasions. The other four teachers did not have any experience of teaching context-based chemistry units. The teachers all taught the same conventional curriculum, which was the nationally standardized chemistry curriculum in the Netherlands.

The coach had been one of the pioneers in the early days of this particular curriculum innovation. He was one of the first designers of context-based chemistry units and taught these units at his own school. Before participating in this study, the coach had two years of experience in coaching teachers to teach context-based chemistry units. The researcher (author of this thesis) was a PhD-student having two years of experience in teaching biology at secondary schools and was a participant observer (Creswell, 2007). The students were 14 or 15 years old, involved in pre-university education and had similar educational backgrounds. They had not previously participated in context-based chemistry education.

Materials

The unit, which was taught by the teachers involved setting the context in class of project teams of students and the teacher, that were assigned to solve the problem

Teachers*	School	Years of Experience		
		Conventional curriculum	Context-based education	Teaching the particular unit in this course
Sue	School A	5	0	0
Tina	School B	3	0	0
Chad	School C	35	2	1
Tony	School C	2	1	1
Rich	School D	9	1	0
Rose	School D	7	0	0

Table 1 Characteristics of teachers who participated in the case study
** all pseudonyms, same teachers as in Chapter 3*

of developing a new material to make artefacts. In a product development procedure consisting of two cycles of gaining information, developing, testing and improving the product, the project teams needed to gain information about the new content of the unit and use this as a tool to solve the problem.

Data collection

A case study method was used for collecting the data (Creswell, 2007). Data collection consisted of three mind maps of teacher's associations with context-based education, designed or adapted lesson materials, lesson plans and student assessments, video recordings of discussions in eight meetings and two lessons during instruction, teacher interviews at the interface of preparation, instruction of the unit and teachers' logs during instruction, and a written report by the coach reflecting on the programme.

Data analyses

The qualitative analysis of data was focused on identifying patterns in group dynamics, in terms of factors in group structure and the social interaction of teachers participating in a collaborative setting that influenced and explained the development of their domain-specific expertise. The analysis of data regarding describing patterns in group dynamics followed an inner-case analysis (Miles and Huberman, 1994).

Firstly, the video recordings of the meetings were used as a primary data source. Events (about ten per meeting of various length) were selected in which the social interaction among the teachers was demonstrated in behaviour or expressed in discussions about (i) setting the context in class, (ii) performing the new teacher's role and (iii) teaching the new content of the context-based unit.

Second, these events were interpreted by using information from the other secondary data sources about factors in group structure, regarding teachers' prior experience, their motivation to participate in the programme, their expertise and attitudes to context-based education, and so forth. Also, the reflection of the coach afterwards was used to interpret his intentions and effects regarding his way of coordinating the group.

In a third step, thick descriptions were made of the selected events, based on interpretations of the social interaction and the factors affecting the group structure. The events described were clustered into categories I-III and the patterns were identified by which the factors of group structure influenced the social interaction towards (i) setting the context in class, (ii) performing the new teacher's role and/ or (iii) teaching the new content of the unit, and as such teachers development.

In order to validate the results, critical quotations were selected by the author of this thesis and categorised by an independent researcher who acted as a peer reviewer (Creswell, 2007). When a discrepancy occurred with the analysis of the author, both discussed the interpretation of these events in order to come to an agreement. In addition, the data sources as video recordings, teacher interviews, lesson plans and student assessments, lesson materials, teachers' logs and the reflection reports of the coach were used for triangulation when necessary to categorize, interpret and recognize (a series of) events.

Results

The results are described within the categories of (I) the teachers' engagement with the purpose of the group, (II) the coordination and leadership of the coach, and (III) the roles, status and hierarchy among the teachers. First the relevant events were described, which involved factors in the group structure during the meeting in the professional development programme, that influenced the social interaction, and as such teachers' development of domain-specific expertise in teaching a context-based unit. Based on these findings, patterns in group dynamics were identified and described in general.

(I) Teachers' engagement with the purpose of the group

Teachers were recruited to participate in the professional development programme for two main motivational reasons. First, the upcoming curriculum innovation and facilitation in coaching and remuneration were used as extrinsic motivators. Secondly, their personal intrinsic motivation was evoked by demanding their professional expertise and experience as teachers, in order to contribute to this curriculum innovation and to give advice to the curriculum developers. Also, the teachers reported the reasons for participating and showed their curiosity and interest in contributing to the new curriculum and learn new approaches to teaching and finding a solution to problems in their own teaching practice. One of the teachers stated in the first meeting:

> *'I wanted to join this group, because I noticed there was a change happening in chemistry education, and I wanted to experience it myself. A few years ago I tried one of the first developed context-based units, and it did not work for me. But maybe that will change when I join this group.' [Event meeting-1]*

The method of recruiting resulted in a group of six teachers having various amounts of teaching experience. Two pairs of teachers came from the same school. One pair of teachers had already taught an earlier version of the unit, but these teachers had experienced many difficulties in influencing the students' learning as intended and decided that participating in this group could support them.

From the teachers' perspective, the two purposes of the group were that the teachers were supported in developing domain-specific expertise in teaching a context-based unit and that they would give advice about whether the units could be taught in their own school situation. This double purpose was maintained during the case study and expressed in the role of the coach and surprisingly in the role of the researcher (author of this thesis). The coach fulfilled the role of the most experienced teacher in teaching context-based units, and the teachers pointed at him when they were asking questions or were asking advice about how to teach the unit in their own school situation. The coach provided the teachers with useful literature, and shared his own experiences, focused the discussions, structured the results and asked reflective questions during the meetings. One event in the first meeting points out this role of the coach:

> *One of the teachers asks how many time instruction of this unit takes in class. The coach answers that it is most important that students understand the essence of the content of the unit, but that not all of the students need to know every detail. When students are used to work in project teams and divide the tasks that need to be done, they can do it in a shorter period, than when they work in projects for the first time. The same goes for the teacher, when he works with project teams for the first time. According to his experience, the unit includes 13 regular lessons, but this depends on the teacher, the students and the particular school situation. The teacher comments that the students have to guide each other in the first place. Another teacher relates this to her own students, some with learning problems, others just difficult to handle: 'What to do with them? Put them together in a team, or separate them?' The coach answers that of course he does not know her students, and cannot tell her what to do. However she needs to make sure that the project teams do function well, to achieve the intended effects of the unit on the students. [Event meeting-1]*

It was planned that the researcher had a passive role in the group and she was presented as an observer during the meetings. However, to stimulate teachers to give advice and share experiences, there was a need for someone to point to when giving this advice. This could not be the coach at this stage, without him jeopardizing the status of most experienced teacher. The researcher responded to this need by adopting the role of the least experienced teacher in the group. This was actually true, so this role was easy to 'play'. In this role she was able to ask questions about how teachers would teach the unit in their school, how they would adapt the unit, and other reflective questions, so teachers shared their experiences and especially they made their initial domain-specific expertise explicit. This reminded them of a situation in which the teachers gave advice about the programme or about teaching the unit in their own school situation and pointed at her to explain, and so the sharing of experiences and expertise among teachers was enhanced.

> *The coach gives the teachers additional lesson material to use during instruction of the unit in class. Then the teachers start to make lesson plans. In the meantime they exchange more experiences of teaching in their own school situations. The researcher participates in the discussions by asking questions about how the teachers would instruct the unit in their own school situation, what they think about making the lesson plans, and why they made changes when they adapted the unit to their own school situation. The teachers explain this to her from the perspective of their own practice. [Event meeting-4]*

This gave the researcher an unexpected active role in the group that was useful to continue and that elaborated the double purpose of the group. The casting between coach and researcher supported the engagement of the teachers in the discussions of the group, as teachers pointed towards the coach when they wanted background information or help to teach the unit, and they pointed towards the researcher when they gave advice about the attainability of teaching the unit in their own school situation. This stimulated the social interaction towards sharing of experiences and expertise, which enhanced teachers' development.

Based on these described events, Pattern I in group dynamics, named 'Double Purpose of the group', was identified and formulated as follows: Teachers are engaged in the discussions in the group to develop domain-specific expertise to teach a context-based unit by deluding a 'double two-way purpose' to participate: 1. They are facilitated to prepare themselves with intensive guidance on the upcoming curriculum innovation; 2. They are assigned to advice the curriculum developers about the implementation of the curriculum in regular schools. The casting between coach, as most experienced teacher and researcher, as least experienced teacher, continues and stimulates this 'double purpose' during the discussions in the meeting, stimulates teachers' sharing of experiences and expertise during the discussions in the meetings and so enhances their development of domain-specific expertise.

(II) The coordination and leadership of the coach

Every meeting the agenda started with 'sharing of teachers' individual experiences, followed by instruction in how to use these experiences in group performances to teach the context-based unit. During the meetings, the coach coordinated the discussions towards sharing teachers' experiences of, for example, adapting the unit and making lesson plans for their own school situation.

An important aspect of this was that the coach created opportunities for the teachers to express their frustrations about their school situation, the problems they experienced in daily practice, and their criticisms of and insecurities about implementing the new curriculum. The coach focused on the frustrations and criticisms and then asked the teachers what 'we' could do about it when teaching this unit. This was effective in directing the discussions towards the planned activities and topics of the meetings and this prevented teachers to criticize other teachers, or the coach to prescribe how to teach the unit. The following event from meeting-1 is an example of how the coach guided the discussion, without prescribing how to teach the unit and using the contributions of the teachers.

> *Rose shares her view on teaching context-based units and explains that students need to think instead of doing tricks. According to her, the students are used to copying the information that they get from the teacher, instead of supplying their own information. By teaching this unit, students cannot just copy, but they need to think to solve problems because they don't have prior knowledge. The coach confirms that this is one of the major characteristics.*
>
> *In addition, Chad, the experienced teacher, confirms and illustrates this with examples of activities in the unit, in which students need to think for themselves in order to solve the problem in product development. Rich recognizes that students learn to do tricks, and gives examples of situations in his classroom in which students perform activities without knowing why, and expects the teacher to approve of or correct this behaviour. He adds that it would help to tell students that the teacher does not know the answer either, but that they could search for the answers together. However students need to get used to that.*
>
> *The coach adds that the teachers need to get used to that as well. Tina expects that she finds this difficult as well. The coach shares his experiences by giving an example of how he delivers a specific activity in class, what questions he would ask the students, shares tips about how to handle specific student difficulties, and how he and the students have got used to this way of teaching and learning.*

He explains that it costs time to change practice, and that the teachers could ask an assistant to correct them when falling back into conventional practice. [Event meeting-1]

In addition, the coach emphasized important aspects, but added that teachers need to find their own way of performing the new teacher's role and setting the context in class.

The coach shares important aspects in managing project teams and collaborative learning. Rich asks about the most obvious pitfalls that other teachers experience when teaching the unit. The coach not directly answers this question, but emphasises that guiding students in project teams requires a lot of energy from the teacher, although students are supposed to perform the activities independently.
This remark stimulates Chad to add that he experienced guiding the students as a difficult aspect of teaching the unit. The coach continues to share the difficulties he experienced in the past concerning management of project teams. He explains that it is difficult to let students do the work instead of doing it yourself. The first time it will take more time to teach the unit, before the teacher gains experience. Chad confirms the experiences shared by the coach. The coach points out that he has been teaching this way since 1990, and that the first years were difficult. So teachers do not need to expect too much of teaching the unit the first time, and they need to find their own way. [Event meeting-1]

The coach had to be aware of this threat of prescribing all the time, in order to create an atmosphere of ownership in the group. In the second meeting the following event occurred:

When the coach structures the factors for successful teaching on the whiteboard, he talks to the teachers as if they were students. One of the teachers corrects him, saying that she is not a student. The coach changes the formulation of the sentence. [Event meeting-2]

Based on the way that the coach implemented the activities on the agenda, coordinated the discussions and communicated with the teachers, the second pattern in group dynamics, named 'Leadership towards sharing' was identified and formulated: during the discussions, the coach coordinated and directed the discussions towards sharing teachers' experiences in teaching the unit in their own classes. By following up the sharing with an instruction to use the experiences in group performances, teachers were prevented from criticizing each other's practice. The coach created a respectful learner atmosphere, in which teachers are stimulated to develop new domain-specific expertise collaboratively by teaching the context-based unit. However, one can imagine that this could cause a lot of time to be spent on practical issues about teaching the unit in class. This could be at the expense of developing the intended domain-specific expertise.

(III) The roles, status and hierarchy among the teachers

Patterns I and II influenced the development of teachers' domain-specific expertise in a mainly positive way. However, these patterns (I and II) did not explain why teachers did not development the whole set of the intended domain-specific expertise (Chapter 2; Dolfing et al., 2012), especially when teachers did not develop the expertise related to (iii) the teaching the new content.

Relating teachers' development of domain-specific expertise to events during the meetings, remarkable events occurred concerning the interaction and the roles of the group members. In meeting-1 the roles, status and norms of social interaction among the teachers emerged during the discussions, which were coordinated by the coach.

> *The coach explains the theoretical background based on what the unit was designed for. He relates what will be expected from the teachers, namely that they develop expertise in teaching this unit in class, which involves setting the context in class for project teams to solve the problem to design new material to make artefacts, performing the new teacher's role of senior member of the project teams and teaching the new content necessary to solve the problem in product development. Chad (who taught the unit before), immediately reacts to that, by sharing from his own experience that it is very difficult to teach this unit because it is so different from teaching traditional chemistry subjects. The coach says that he is more than welcome to share his experiences, and that it can be very helpful for others. [Event meeting-1]*

The coach used the experience of Chad in support of the theoretical background of the context-based unit, and placed Chad in the role of the more experienced person in the group. In meeting-1 'seeds were planted' to develop expertise in setting the context, perform the new teacher's role, and teaching the new content.

The teachers are assigned to study the unit. Chad asks whether it is permissible to adapt the unit, because from his experiences he thinks the unit needs to adapt to his own school situation. The coach says that they could discuss that in the group. [Event meeting-1]

In the event above, the coach used the question to bring up one of his prior intentions to let the teachers adapt the unit to their own school situation, to study it well and acquire new domain-specific expertise as a side effect.

Chad relates his positive experiences when teaching the unit. He thinks it was a nice way to introduce chemistry to the students. The coach refers to this and emphasizes the positive attitude of other teachers (he knew of) about teaching the unit. [Event meeting-1]

The coach used these feelings of Chad about teaching the unit to create a positive attitude among other teachers towards teaching the unit and the curriculum as a whole. This was necessary to avoid other teachers resisting trying this new teaching approach. In the following meetings Chad expressed more and more of his experiences and troubles in organizing project teams in class.

Teachers are asked to formulate their own learning goals. All the teachers mention their personal difficulties. Chad mentions that his main difficulty is organising project teams in class. Although the other teachers have totally different learning goals, in the rest of the meeting teachers only discuss how to organize project teams in class, what to do with specific individual students, how to guide the teams at a distance, how to perform the role of the senior member of the project teams, and so forth. The other teachers and the coach ask Chad to tell more about his experiences when teaching the unit for that matter. [Event meeting-3]

The coach presents different roles teachers could perform in class. The teachers are assigned to think about what and how to perform the role of senior member of the project teams, using the roles presented as examples. Instead, initiated by Chad, the teachers follow ways of organizing project teams in class. They weigh the advantages and disadvantages of organizing teams of two, three, or four students. The coach follows the discussion, and shares his own experiences with the teachers [Event meeting-4]

Halfway in the meeting, the coach states that the teachers did not discuss the content of the unit enough. He asks whether it is not necessary anymore, because the teachers understand the new content and know how to teach it, and wonders whether organising groups is the main problem at the moment. The teachers confirm, and continue the discussion about organizing the project teams. [Event meeting-4]

The teachers explain what they wrote in their lesson plans. They all start to explain how they were going to organize the project teams, for example by organizing teams of two, four, six students, and how the task will be distributed within and among the project teams. In addition, the teachers express their own learning goals that need to be achieved during instruction. Besides the other goals, they all want to expand their expertise in organizing and guiding project teams in class. [Event meeting-5]

These events show that the contributions of the teacher (Chad), who had some experience in teaching the unit, were used by the coach to direct the discussions in the meetings. These contributions were then considered by the other teachers as being more important than the other contributions. By using the contributions, he gave the teachers the feeling that they could influence the activities of the group and so their learning process. However, using mostly the contributions of Chad, consequently this influenced the direction of the discussions, and so on teachers' development of domain-specific expertise.

However, the more experienced teachers had problems in setting the context in class and performing the role of a new teacher. Even when one of the teachers brought the issue of content up in the first meeting, by asking: "How should students study and how should we assess the new content by teaching this unit?" the coach did not pay attention to this question, and Chad invalidated the question by saying that this was not the problem. The factor of hierarchy among group members, based on their prior experience, influenced the social interaction and meant that the new content was discussed less during the meetings.

Pattern III, 'Hierarchy based on prior experience', could be identified and formulated as: 'In a group, a hierarchy develops among the teachers based on their prior experience of teaching context-based units'. The contributions to the discussions of the more experienced teachers are considered to be more important than those of other teachers. For the coach, it will be useful to make these contributions productive in order to guide and direct the discussions. Consequently, the focus of the discussion was directed by the input of the more experienced teachers and as such this influenced the development of domain-specific expertise.

Discussion

The aim of this study was to identify the patterns of group dynamics that influence and explain the development of the domain-specific expertise needed in a professional development programme to support teachers in teaching a context-based unit. This study resulted in the identification of three patterns in group dynamics. Pattern I *Double group purpose* and Pattern II *Leadership of the coach towards sharing* influenced the development positively. The lack of teachers' development in teaching the new content was mostly explained by Pattern III: *Hierarchy among the teachers based on experience of teaching context-based units*. The hierarchy and roles among the group members were of great influence on the social interaction and the focus of the discussions and thus on teachers' development of domain-specific expertise.

In an attempt to find an explanation of why and how these patterns influence teachers' development, the relationship of these patterns to teachers' motivation and engagement in the programme and the establishment of roles to enhance teachers' sharing were discussed. In addition, recommendations and opportunities for further research are provided in order to implement these patterns as strategies as part of a professional development programme.

To achieve group performance and collaborative behaviour, learners, in this case teachers, need to be motivated intrinsically and extrinsically (Miller et al., 1998), as motivation is the result of forces that pull or push the individual in certain directions (Wlodkowski, 2003). In addition, when teachers formulate their own activities and goals (Brouwer et al., 2012) and share their experiences (Naquin and Holton, 2001), teachers become engaged in the purpose of the group and teachers feel ownership towards the curriculum innovation (Ketelaar, Beijaard, Boshuizen and Den Brok, 2012). This study combines these notions and adds that the way teachers are recruited to participate in the programme influences and even determines teachers' motivation and engagement during the programme.

Setting the double purpose of giving advice about curriculum innovation and professional development motivates teachers because they are put into the role of expert in their own practice and an appeal is made to their experience. This creates a setting in which teachers are approached as professionals that contribute to curriculum innovation, and learn and develop as a natural course of action. Also, by giving advice, teachers share experiences and make their initial and developed expertise explicit, which is important to enhance collaborative learning (Breu and Hemingway, 2002; Wenger, 2000). This is an important and promising new understanding of why and how collaboration enhances teacher development. Further exploration could give insight into how this pattern could be used as a strategy in professional development programmes.

Secondly, the establishment of roles in the group and the influence on teachers' development are discussed in relation to the patterns identified. Although group roles, norms and communication patterns must be established by self-organisation (Ashby, 1962), this study shows that the roles and status among teachers in a collaborative setting are determined by their prior experience in teaching context-based education. The understanding can be used productively when designing professional development programmes. Group composition and role play can be planned in such a way that it enhances teacher development.

It is known that teachers' own identity, pride and respect influences their values and attitudes towards group and cooperative behaviour (Tyler and Blader, 2001) and that different roles among group members can result in power relations that influence inter-group behaviour, social interaction and development (Sachdev and Bourhis, 1991; Sjøvold, 2007). This study shows how these power relations and the social interactions among teachers emerge and how these can influence the direction in which teachers develop, by determining the content of discussions among the group members. Being aware of these patterns makes it possible to use them to direct discussions in collaborative settings.

From the perspective of group dynamics, the following recommendations can be made when composing a collaborative setting in a professional development programme to support teachers in curriculum innovations. In relation to the double purpose of giving advice and learning and development and the roles of the group members, not only can a role as expert (coach) enhance teachers learning, but in addition a role as a novice can enhance teachers' experience of sharing. This social interaction of sharing expertise enhances teachers' development. The role of novice cannot be performed by one of the teachers without losing their identity as a professional and an expert in teaching in their own school situation. In addition, the coach cannot perform this role, in addition to his role as most experienced teacher in the domain of curriculum innovation. An external person who fulfils the role of least experienced teacher can enhance teachers' sharing of experiences and their initial (tacit) expertise. This is a new and promising aspect of how group dynamics influences teachers' development in a way that is relevant for further exploration.

This study is a contribution to designing professional development programmes in which teachers learn and develop in collaborative settings (Brown and Duguid, 1991; Butler et al., 2004; Swan et al., 2002; Vescio et al., 2008). It shows how patterns in group dynamics influence teachers' development. By understanding this influence, the designers of professional development programmes can intentionally make productive use of such patterns to facilitate the intended teacher learning. However, more research is necessary to understand how these patterns in group dynamics can be incorporated in frameworks and activities for professional development as explicit strategies to support teachers in specific curriculum innovations (Stolk et al., 2012).

In addition, further research is necessary to understand how hierarchical and power relations can be used to enhance teachers' development, by influencing the roles of the group members. The composition of teacher groups will always be heterogeneous, taking the experience, background, school situation and initial expertise of teachers into account. Understanding the influence of the hierarchy and power relations that emerge because of that heterogeneity could help to direct the social interactions towards the new aspects of a curriculum innovation, and as such teachers' development. Patterns in group dynamics and the influence of various factors on teachers' development vary among cultures and nationalities. An interesting subject for research would be why and how factors such as social interaction, nonverbal communication, hierarchy and status influence teachers' development in non-Western cultures.

The validity of these patterns is the subject of several restrictions. Our study involves a single case study, which was carried out in an initial stage of implementing a curriculum innovation. The teachers are likely to be unrepresentative of the majority of teachers in terms of curriculum innovation in the Netherlands (Van Driel, Bulte and Verloop, 2005). Whether patterns in group dynamics could be found in general in collaborative settings in this or other curriculum innovations requires further investigation. Besides being based on a single case study, the results do not give insight into the influence of group size, which might have a great influence on social interaction and group decision making (Ohtsubo and Masuchi, 2004). This study is a first step in reflecting teachers' development in collaborative settings from the perspective of group dynamics. Further research is necessary to understand the relationship between group dynamics among small groups of teachers and the individual development of the group members, collaborative behaviour and the group performance of the whole group.

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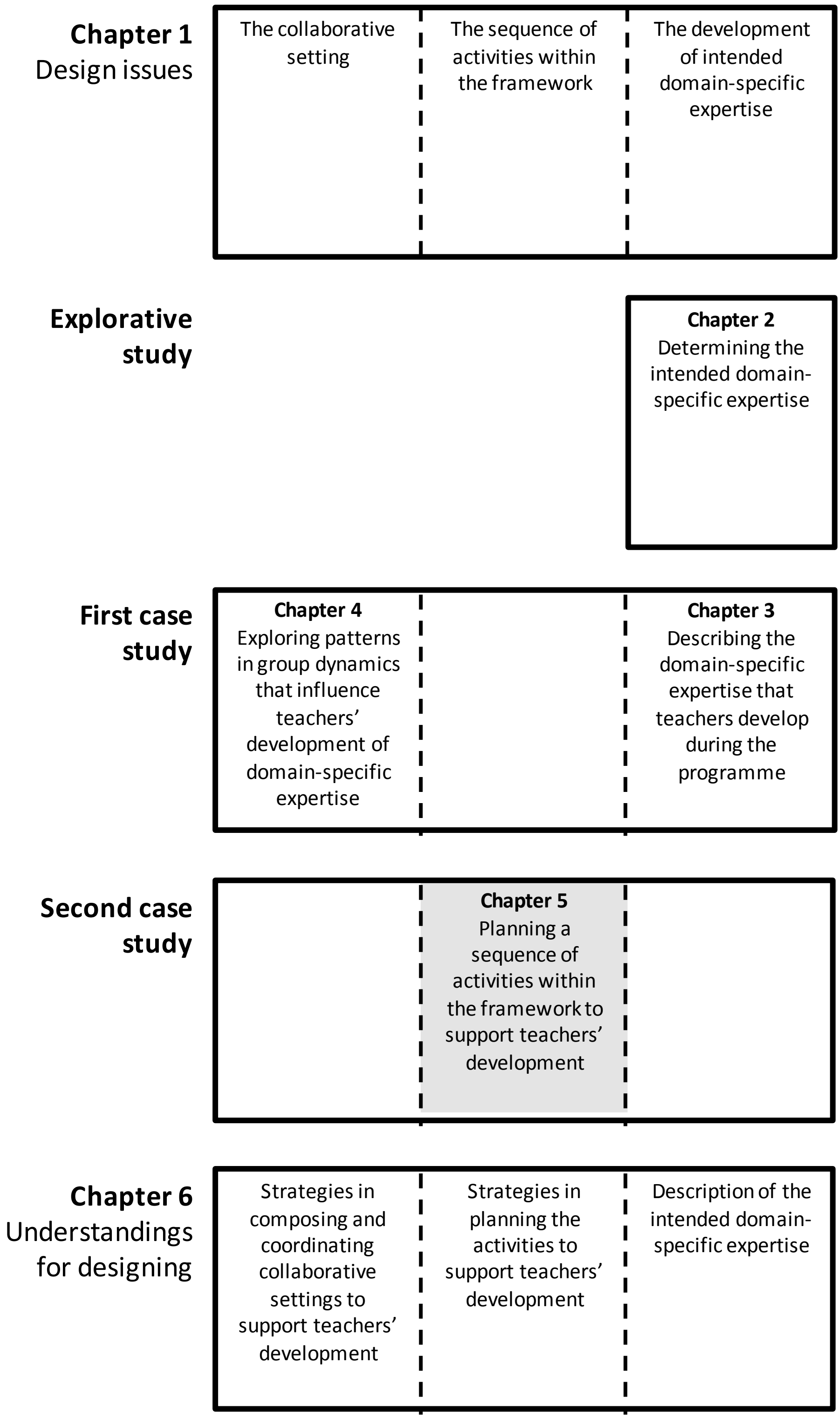

Chapter 1
Design issues
The collaborative setting
The sequence of activities within the framework
The development of intended domain-specific expertise
Explorative study
Chapter 2
Determining the intended domain-specific expertise
First case study
Chapter 4
Exploring patterns in group dynamics that influence teachers' development of domain-specific expertise
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Chapter 6
Understandings for designing
Strategies in composing and coordinating collaborative settings to support teachers' development
Strategies in planning the activities to support teachers' development
Description of the intended domain-specific expertise

Chapter 5

Facilitating Teachers' Sense-Making in Macro-Micro Thinking in Context-based Chemistry Education[1]

Abstract
The aim of this study was to evaluate an adapted framework for teachers' professional development to support their sense-making of three aspects of context-based chemistry education. In a case study, seven teachers participated in a professional development programme to accommodate their personal frame of reference regarding setting a context in class, performing the new teaching role, and teaching the new content. A qualitative inner-case analysis was conducted to describe teachers' sense-making during the programme. The results showed that the professional development programme led to teachers' accommodation of all three aspects. The influence of an additional phase in the framework to facilitate teachers' sense-making in teaching the new content was discussed. The implications for planning professional development programmes to support teachers in curriculum innovations are discussed.

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[1] This chapter is submitted as:

Dolfing, R., Prins, G.T., Bulte, A.M.W., Pilot, A., Vermunt, J.D. (*submitted*). Facilitating Teachers' Sense-Making in Macro-Micro Thinking in Context-based Chemistry Education.

Introduction

Redesigning science curricula in terms of context-based, competence-based or inquiry-based programmes often implies the teaching of new domain-specific content, for example in biochemistry, material science and food technology, that is not part of a teacher's regular expertise (Bulte, Westbroek, de Jong and Pilot, 2006; De Putter-Smits, Taconis, Jochems and Van Driel, 2012; Lee, Hart, Cuevas and Enders, 2004; Meijer, Bulte and Pilot, 2009; Pilot and Bulte, 2006; Wesselink, 2010). The development of the new teaching expertise preferably takes place in professional development programmes in which teachers learn collaboratively (Van den Akker, 1999; Vos, Taconis, Jochems and Pilot, 2010). This working together in collaborative settings is said to be a promising strategy for teacher learning and development (Brouwer, 2011; Brown and Duguid, 1991; Butler, Lauscher, Jarvis-Selinger and Beckingham, 2004; Swan, Scarbrough and Robertson, 2002; Vescio, Ross and Adams, 2008), for educational innovation (Bakkenes, Vermunt and Wubbels, 2010), for school improvement (Harris and Jones, 2010) and for the teaching and development of curriculum units (George and Lubben, 2002; Whitcomb, Borko and Liston, 2009).

For successful professional development, teachers make sense of the curriculum innovation in the light of their own knowledge, beliefs and experiences, the situation in which they find themselves, and the design and message of the policy for implementing the innovation (Ketelaar, Beijaard, Boshuizen and Den Brok, 2012; Spillane, Reiser and Reimer, 2002). In this process of sense-making, teachers interact between their own frame of reference and the perception of the situational demands that are inherent in innovations, resulting in the personal interpretation of innovations (Luttenberg, Veen and Imants, 2011). A professional development programme to support this process of sense-making, and adequate problem analysis of the curriculum innovation in relation to the conventional curriculum is an essential element (Handelzalts, 2009; Voogt et al., 2011).

Insufficient problem analysis of the new content could, however, cause teachers stress and affect their coping during the programme (Chapter 3; Dolfing, de Jong, Bulte, Pilot and Vermunt, 2011; Stolk, De Jong, Bulte and Pilot, 2012). As teachers' expertise in teaching the (new) content is a prerequisite for further experience and therefore development in and beyond a professional development programme (Van Driel, Verloop and de Vos, 1998), a lack of understanding of the new content could hinder teachers' continuous and sustainable professional development with regard to teaching the innovative curriculum (Armour and Yelling, 2004). The question is how teachers can be facilitated to conduct an adequate problem analysis of teaching the new content in a professional development programme.

The aim of this study is to evaluate a professional development programme to support teachers' sense-making in teaching context-based chemistry education, including an additional sequence of activities to facilitate teachers in conducting an adequate problem analysis of teaching the new content. This additional sequence of activities was expected to prevent teachers experiencing a high level of stress and using coping strategies that hinder their sense-making and development in teaching context-based education.

Teachers' sense-making in context-based chemistry education

Teachers' sense-making of context-based education, can be considered as a search for an agreement between teachers' personal frame of reference in teaching the conventional curriculum and that of teaching the new curriculum. Sense-making can be defined as the interaction between one's understanding and perceptions of situational demands regarding the curriculum innovation (Coburn, 2004; Coburn, 2005; Spillane et al., 2002).

Luttenberg et al. (2011) present a model to distinguish two dimensions and four types of sense-making of curriculum innovations. The poles of the first dimension refer to the extent to which the teacher's frame of reference corresponds to the demands that he or she perceives in connection with reforms (match/mismatch). The second dimension refers to the extent to which the individual frame of reference or the perceived demands of a reform predominant at a particular point in time can be identified (own frame of reference/ other frame of reference. When combined as depicted in Figure 1 the two dimensions of teachers' sense-making identified above produced four possible types of sense-making: assimilation, accommodation, toleration and distantiation.

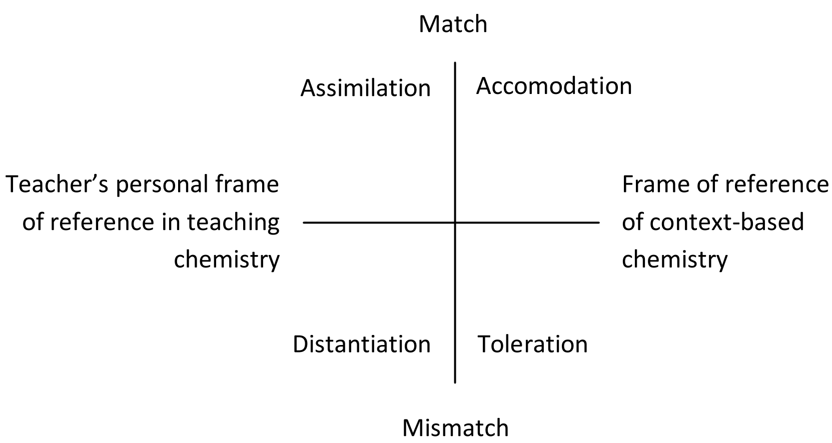


Figure 1 The two dimensions and four types of teachers' sense-making of curriculum innovation (Luttenberg et al. 2011).

The first type of sense-making is assimilation, which means that the teacher uses his or her frame of reference in the sense-making process and adapts new ideas in such a way that they fit into the existing frame. This results in a variation within his or her frame of reference. The second type of sense-making is accommodation, in which the teacher transforms his or her own frame of reference in such a way that it fits in with the situational demands. The situational demands predominate in this type. The third type defined is toleration, whereby the teacher accepts the new situational demands but at the same time maintains his or her own frame of reference. The teacher holds separate perceptions about teaching. The last type of sense-making is distantiation, whereby the teacher rejects the situational demands and continues to use his or her initial frame of reference. Different combinations of the four types of sense-making on different subjects can be espoused by one teacher (Ketelaar et al., 2012; Luttenberg et al., 2011).

In this implementation of a curriculum innovation, teachers are intended to develop expertise in teaching context-based chemistry education in a sustainable way. Therefore, teachers need to accommodate their personal frame of reference to fit the frame of reference of teaching context-based chemistry education. When the process of assimilation occurs, teachers recognise aspects of the innovation such as teaching research activities or guidance of students in collaborative learning approaches, which are already part of their expertise, so there is no motivation for further development. If teachers only tolerate the new aspects of context-based education during the professional development programme, they could easily drop them afterwards. In that case development would be neither sustainable nor continued after the programme. When teachers distantiate themselves from teaching the new content in food technology or material science, they do not develop expertise in teaching this new content.

Sense-making, especially accommodation, is considered as an active, cognitive and emotional process in which a person attempts to fit new information into existing expertise and beliefs (Spillane et al., 2002; van Veen and Lasky, 2005). The process of sense-making involves emotions, motivations, self-efficacy, stress, beliefs and attitudes of the learning professionals in a changing domain of practice (Bakkenes et al., 2010; Dolfing et al., 2011; Dolfing, Bulte, Pilot and Vermunt, 2012; Luttenberg et al., 2011; Thompson, 2005). The change could lead to feelings of stress and incompetence, thereby reducing teachers' self-efficacy and self-esteem (Brown, Ralph and Brember, 2002; Evers, Brouwers and Tomic, 2002; Kokkinos, 2007), especially in relation to new content (Hingant and Albe, 2010; Tuvi-Arad and Blonder, 2010). Coping strategies to avoid feelings of stress have been described that occurred when teachers did not succeed in finding agreement between their personal frame of reference and the new frame of reference of curriculum innovations (Evers et al., 2002; Parker and Martin, 2009). These coping strategies involved blaming the (lack of) abilities of the student and the quality of the lesson materials or expressing the intention to drop out of the programme.

Context-based chemistry education in this study

This study is situated within the curriculum innovation of context-based chemistry education in the Netherlands (Bulte et al., 2006; Meijer et al., 2009; Prins, Bulte, van Driel and Pilot, 2008; Stolk et al., 2012). This curriculum innovation involved the design of innovative context-based units. In addition, teachers participated in professional development programmes, in which they were intended to develop the required domain-specific expertise in a collaborative setting (Domitrovich et al., 2009). This domain-specific expertise involved the new aspects of (i) setting a context in class, (ii) performing the new teacher's role and (iii) teaching new content (Chapter 3; Dolfing et al., 2011).

In exemplar units of this curriculum innovation the new content and teacher's role in relation to students are determined by the context setting (Meijer et al., 2009; Prins, Bulte and Pilot, 2011; Westbroek, Klaassen, Bulte and Pilot, 2010). The 'context' in context-based education is conceived as the setting of a social activity within which the student's behaviour and mental experiences are situated and which uses the relationship between situated background knowledge and specific language (Gilbert, 2006; Gilbert, Bulte and Pilot, 2011).

In this particular curriculum innovation, the context-setting requires teachers to organise and manage project teams consisting of students and a teacher who have to solve a problem in product development. Students need the new content as a tool to solve this problem. To gain information, students need to perform general research activities. In the conventional curriculum, teachers are often used to teach the chemistry content directly to the students, or they use contexts as examples to illustrate how the content is used in practice. Teachers need to accommodate the understanding that the problem as set in the context determines the content that is being taught. The project teams learn the content when using it as a tool to solve a problem.

In the context-based curriculum, the teacher acts as the senior member of the project team and guides the students in product development procedures. This means that students are motivated to take ownership of the problem. Consequently, teachers use different pedagogical approaches, stimulating students' self-regulated learning to create a different balance in student- and teacher-centred instruction compared with teaching of the conventional curriculum. The teacher also helps students to create, order, structure and anchor new knowledge on the basis of existing knowledge by keeping an overview of students' performance of activities, monitoring student learning through assessments, giving instructions to students in class, and so forth.

In the conventional curriculum teachers have the role of the expert who knows the answers to the questions in the book, knows what conclusions are drawn from general experiments and lab activities, and so forth. The teacher often values student answers to questions from the teacher or from the book in a way of 'right' or 'wrong' (Mortimer and Scott, 2003). Teachers need to accommodate the idea that, acting as a senior member of the project team, they do not know the answers or problem solution. Instead, they are more experienced in, for example, performing research activities, setting up experiments and finding literature to gain more knowledge about materials and products, and they provide students with overviews and summaries, help students to relate conclusions of experiments to theoretical knowledge from books, guide students in formulating questions and searching on the internet for more information, organise lab activities in class, monitor student learning during the problem-solving processes, and so on. This constitutes the new teaching role, and is a huge shift in terms of teaching practice.

This study especially focused on teachers' sense-making of the aspect of the new content in context-based chemistry units. The 'new' frame of reference concerned the content of the unit that involves macro–micro thinking using meso-levels in structure–property relations (Dolfing et al., 2011; Meijer et al., 2009). For chemistry teachers, this content is a new experience in classroom teaching, as conventional macro–micro thinking is directed towards learning about particles such as molecules and atoms (micro-level), and direct relations of properties at the macro-level (Taber, 2009), as shown in the conceptual scheme in Figure 2. In addition, teachers often do not make the macro-micro thinking explicit for students.

As setting the context involves the social activity of product development, the properties of products at the macro-level are mostly explained by using structures at levels between the macro- and micro-levels. Therefore, a product is considered as a structure (macro-level) consisting of several substructures (meso-levels). This conceptual scheme is shown in Figure 3. When addressing a problem in the unit, students start with the implicit use of macro–micro thinking, which is gradually expanded during the project, as they explain and predict the properties of the product on the macro-, meso- and micro-levels. During product development activities, the macro–micro thinking is made explicit by formulating the structure–property relations in sentences, such as: 'IF a structure X consists of interacting substructures X_1, X_2, X_3, etc., THEN structure X has property A'. Continuing to zoom in on structure X in Figure 3 would result in the following structure–property relations: 'IF a substructure X_3 consists of interacting substructures X_{3a}, X_{3b}, X_{3c}, etc., THEN substructure X_3 has property B' and 'IF a substructure X_{3c} consists of interacting substructures X_{3ci}, X_{3cii}, X_{3ciii}, etc., THEN substructure X_{3c} has property C'.

This system of nested structures and properties and the explicit relations among them result in the explicit formulation of a 'mental map' (Gilbert et al., 2011) of

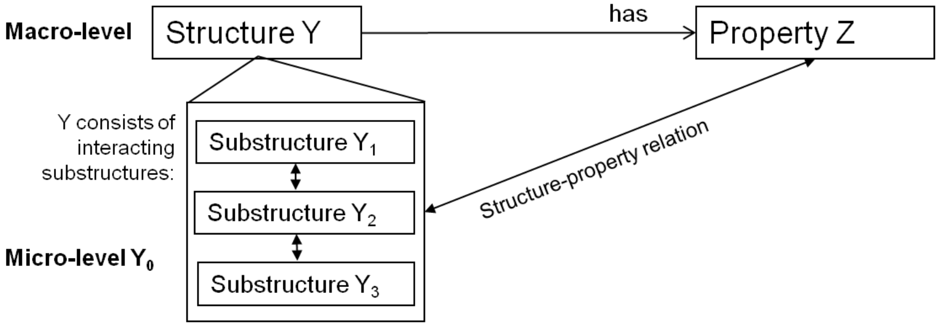


Figure 2 Conceptualization of macro–micro thinking in the traditional chemistry curriculum

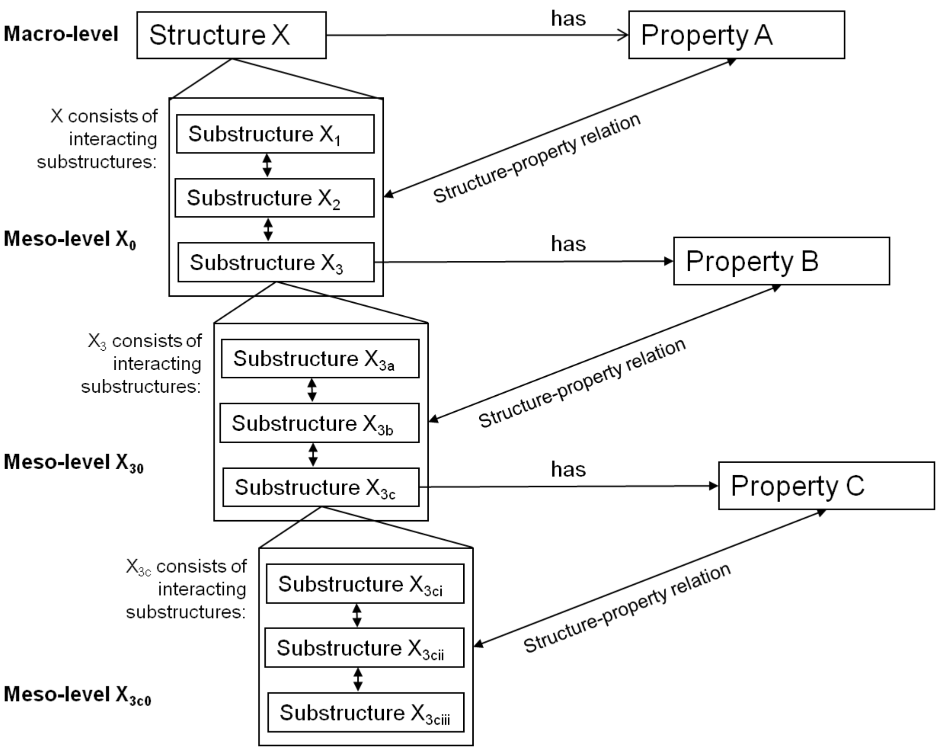


Figure 3 Conceptualization of macro–micro thinking using meso-levels in structure–property relations

macro–micro thinking using meso-levels with regard to structure–property relations. Depending on the type of problem, a number of different meso-levels may be relevant, and a certain set of structure–property relations will be necessary until sufficient structures, properties and interrelations are available to solve the product development problem at hand. Structures of atoms and/or ions at the micro-level in a certain pattern should only be used when it is necessary to address the problem of developing a product which has the desired properties.

To teach and make the new content explicit for their students, teachers need to accommodate the frame of reference for teaching the macro-'meso'-micro thinking in structure-property relations (Figure 3) into their personal frame of reference for teaching macro-micro thinking in the conventional curriculum (Figure 2). This involves the categories:

1. relating structures to properties in a material
   (Structure X has Property A);
2. zooming into structures to determine substructures on meso-levels in a material
   (Structure X consists of substructures X_1, X_2, X_3, ...);
3. explaining properties by describing the interacting sub-structures in a material
   (IF a structure X consists of interacting substructures X_1, X_2, X_3, etc., THEN structure X has property A).

Planning the sequence of activities in a professional development programme

For successful implementation of context-based chemistry education, it is recommended to support teachers to accommodate their frame of reference to incorporate the aspects of (i) context-setting in class, (ii) the new teacher's role and (iii) the new content of macro-'meso'-micro thinking. Several initiatives have been described in which teachers develop when they collaboratively teach context-based units (Butler et al., 2004; George and Lubben, 2002; Handelzalts, 2009; Voogt et al., 2011; Whitcomb et al., 2009). The strategy of collaborative learning was used to enhance teachers' beliefs that they could succeed in implementing an innovation in their own school situation (Abrami, Poulsen and Chambers, 2004).

Stolk et al. (2012) described a framework for teachers' professional development designed to empower teachers to teach context-based chemistry units in a collaborative setting. The framework consists of three phases:

- preparation for instructing the unit in order to acquire new domain-specific expertise;
- teaching of the unit in the teacher's own school situation to apply and expand the new domain-specific expertise;
- reflection on teaching actions and effects on students to expand and sustain the new domain-specific expertise for continuous professional development regarding the curriculum innovation.

Phase	Function
Initial	a. Connect to teachers' views on context-based education b. Reveal 'useful' teachers' initial domain-specific expertise
Problem analysis	c. Let teachers discover differences and similarities among their views on teaching the conventional content and teaching macro-micro thinking in structure-property relations d. Let teachers explore strategies for teaching the macro-micro thinking in structure-property relations e. Provide the opportunity for teachers to define their learning goals f. Provide the opportunity to apply the domain-specific expertise in practice g. Give teachers the opportunity to reflect on their teaching and learning experiences h. Examine teachers' development by creating the opportunity for teachers to produce a product i. Evaluate teachers' development
Preparation	c. Let teachers discover differences and similarities among their views on context-based education and the context-based unit d. Let teachers explore strategies for teaching the context-based unit, give examples, and present conditions for use e. Provide the opportunity for teachers to define their learning goals
Instruction	f. Provide the opportunity to apply the domain-specific expertise in practice
Reflection	g. Give teachers the opportunity to reflect on their teaching and learning experiences h. Examine teachers' development by creating the opportunity for teachers to produce a product i. Evaluate teachers' development

Figure 4 The adapted framework for professional development of teachers in teaching context-based units, including a special focus on the additional phase of problem analysis

During the programme, conditional functions need to be achieved for teachers' development. In addition, within each phase of the professional development process, functions need to be fulfilled to facilitate teachers in developing expertise to teach context-based units successfully (Stolk et al., 2012).

It was found, however, that a professional development programme based on this framework does not necessarily facilitate teachers in developing expertise in teaching the new content (Chapter 3; Dolfing et al., 2011). A lack of understanding in (iii) macro-micro thinking in structure-property relations hinders teachers in making decisions in teaching strategies in the other aspects of context-based education, and involves (ii) performing the new teacher's role and (i) setting the content in class. Consequently, this lack of understanding influences teachers' development in terms of teaching the context-based unit.

To prevent teachers' development being hindered, a phase could be added in which teachers conduct a problem analysis of the new content of macro-micro thinking in structure-property relations (Dolfing et al., 2011; Handelzalts, 2009; Voogt et al., 2011). This is an important phase because, when teachers participate in collaborative settings, major decisions in teaching strategies (implicitly or explicitly) are taken before or at the start of the programme (Handelzalts, 2009). This phase should be planned before teachers prepare to teach the unit and before they need to focus on all three new aspects of context-based chemistry education.

This study aims to plan and evaluate a professional development programme based on the framework described by Stolk et al. (2012), including an additional phase of problem analysis, to support teachers in making sense of the new aspects of (i) the context-setting, (ii) the new teacher's role, and (iii) the new content. This sequence of activities especially needs to facilitate teachers in conducting a problem analysis on this new content. The activities of the additional phase of problem analysis are elaborated in the next paragraphs, in relation with the functions to fulfil. The adapted framework is presented in Figure 4.

To support teachers in their problem analysis, additional functions need to be fulfilled in which teachers are introduced to the new content, compare their personal frame of reference of teaching the conventional content and the frame of reference of teaching the new content, and accommodate their frame of reference to teach the new content of macro-micro thinking in structure-property relations. In terms of the functions in of the framework, they are comparable to function a, b in Figure 4. Activities should be planned to let teachers discover the differences and similarities between teaching the new content in the unit and the content in the conventional curriculum in order to make sense of it (function c) (Handelzalts, 2009; Voogt et al., 2011).

In terms of providing teachers with an introduction to the content of macro-micro thinking in structure-property relations, a workshop seems an appropriate activity for learning about new content and pedagogy (Scribner, 1999). It would offer teachers an example of how to teach the new content in class and gain insight into the preferred conditions in their own school situation (function d). In addition, it would prevent teachers spending too much time in discussing practical and organisational issues of teaching the unit and provide them with concrete images of future practice for teaching the unit (Handelzalts, 2009; Scribner, 1999).

Teachers acquire a deeper understanding of content when reflecting on how to teach students (Fernandez, 2005). Similarly to the studies of Dolfing et al. (2011) and Stolk et al. (2012), Fernandez (2005) showed that only during their instructional activities did teachers experience a lack of understanding of the content. When teachers plan (function h), instruct (function f) and reflect (function g, i) on a lesson in their own classes, they discover the expertise they require to develop (function e). This means that to facilitate teachers' problem analysis, activities should provide a quick iteration of preparation, instruction and reflection on teaching the new content and functions need to be fulfilled accordingly. With reference to Fernandez (2005), activities could be planned whereby teachers prepare, instruct and reflect on a lesson in which they teach macro-micro thinking in structure-property relations in their own classes.

Student performance and achievements can play a key role in facilitating teachers become aware of their personal frame of reference. In addition, curriculum materials can be a source of professional development (Ball and Cohen, 1996). Relating teacher development to student learning in the new content could be an appropriate strategy (Fishman, Marx, Best and Tal, 2003). To bring teacher learning, student learning and curriculum materials together in a professional development programme, specific activities should be planned for teachers to formulate and relate their learning goals to the intended learning effects of students of the curriculum innovation (function e). The intended student effects could involve the specific learning effects of the unit, or more general learning goals and achievements of the curriculum innovation (Ryder and Banner, 2011).

In other words, the additional phase involves the functions of the framework regarding preparation, instruction and reflection on a lesson about the new content. These functions are nested in the framework of the programme. The sequence of activities needs to provide teachers with an opportunity to be introduced to the frame of reference on the new content, and to recall their personal frame of reference on teaching macro-micro relations in the conventional curriculum. In addition, the activities need to provide the opportunity to link student learning effects with teachers' learning goals to stimulate teachers. This would mean that teachers accommodate their personal frame of reference towards the frame of reference of teaching macro-micro thinking in structure-property relations.

Scope and Research Question

The scope of this study embraced the evaluation of a professional development programme to support teachers in teaching context-based chemistry units. In the light of teachers' sense-making process of the three new aspects in teaching context-based chemistry education, this study focused particularly on planning a sequence of activities to support teachers in conducting a problem analysis in teaching the new content of macro-micro thinking in structure-property relations. This provided a more general understanding about strategies for teachers' professional development in curriculum innovations. In this study, the research question was formulated as:

To what extent does the sense-making process during the professional development programme, based on the adapted framework, result in teachers' accommodation of
-the specific context-setting in class,
-the performance of the new teacher's role , and especially,
-teaching of the new content in context-based chemistry education?

Method

A case study approach was conducted (Creswell, 2007), that involved seven teachers guided by an experienced coach, who prepared a collaborative setting for teaching a context-based unit. Every teacher was considered as a single case. In this section, first the procedure for designing the professional development programme is described. Second, the sequence of activities to facilitate teachers in their problem analysis on the new content is described in detail. To answer the research question, data collection and analysis were focused on describing teachers' sense-making in terms of (i) setting the context in class, (ii) performing the new teacher's role and (iii) teaching the new content. Specific attention was paid to the description of teachers' sense-making in teaching the content of macro-micro thinking in structure-property relations during the programme, in relation to the additional phase that was planned.

Procedure for designing the professional development programme

The professional development programme was planned by the coach and the researcher (author of this thesis). They organised two sessions to plan the programme in detail. In the first session they discussed in the light of the adapted framework teachers' intended development and the stumbling blocks that might occur. The intention was to achieve agreement about the activities needed to fulfil the required functions. In addition, decisions were made about practical issues such as the duration and the number of meetings of the programme. The coach's experience and his tacit knowledge as a teacher of context-based units provided agendas for the meetings of the professional development programme, which included the schedule of activities. In the second session they discussed the agendas of the meetings. The agendas were also placed in a research perspective to make sure that data could be collected that gave insight into teachers' sense-making in teaching context-based education, especially in teaching the new content of macro-micro thinking in structure-property relations. The coach steered the practical and organisational perspective so that the sequence of activities in the programme was coherent with achieving the task of teaching the unit. The full programme including the phases, functions and agendas of the meetings is presented in the Appendix of this chapter. The activities in the phase of problem analysis in the meetings will be elaborated in the next section in relation to the specific functions.

Sequence of activities to support teachers in their problem analysis on the new content

The phase of problem analysis on the new content of macro-micro thinking involved two meetings of three hours within four weeks. The whole programme consisted of eight meetings within five months. Before teachers participated in the programme, they completed an assignment to describe their personal frame of reference, which involved their initial domain-specific expertise, and their views and ideas about context-based chemistry education. This assignment required teachers to describe their associations with context-based chemistry education in a mind-map. In addition, teachers reported lesson plans, lesson materials and student assessments that in their perspective involved aspects of context-based chemistry education (function a, b). They also reported their motivations and expectations regarding participation in the professional development programme.

In the first meeting of the programme, the coach gave an introduction and overview about the three aspects of context-based chemistry education, namely (i) the context-setting, (ii) the new teacher's role and (iii) the new content of macro-micro thinking in structure-property relations. In addition, he compared these aspects with similar aspects in the conventional curriculum (function c).

Then teachers participated in a workshop about using bamboo as a material to develop different products such as chairs, sweaters, floors, and so on. They needed a deep understanding of the structure and properties of the bamboo to know why and how it could be used as a material for all these different products. This resulted in a conceptual scheme about the structures and properties of bamboo as shown in Figure 3. After the workshop teachers shared prior experiences in teaching chemistry in relation to context-based education (function a, b).

Teachers were then asked to plan a lesson on macro-micro thinking in structure-property-relations represented in the conceptual scheme, teach it to their own students, and reflect collaboratively on their teaching strategies in the second meeting (function d, f, h). It was emphasised that teachers should integrate the new content of macro-micro thinking in structure-property relations within their regular programme and in their own school situation, instead of planning a lesson separate from their regular programme. They were also asked to think of successful events in their conventional teaching that could be useful when they implemented the unit (function a, b).

In the second meeting, teachers shared their experiences and reflected on their teaching strategies and student effects on macro-micro thinking in structure-property relations (function g). First the coach asked how teachers had implemented their lesson plan and asked about their experiences while teaching the lesson. Then other teachers could ask questions. The coach asked teachers to formulate their learning experiences during the instruction of the lesson. When the teachers had difficulty describing their experiences, the coach asked reflective questions to stimulate sharing. Then teachers shared and reported their success events in two groups on a poster (function a, b).

In the light of the teachers' reflections, the coach recalled the example of the conceptual scheme and explained the steps in macro-micro thinking that students needed to take to describe, explain and predict properties by relating them to structures on micro- and meso-levels (function c).

After sharing their experiences, teachers were asked to link them to their personal frame of reference by thinking of successful events in their regular lessons. These events involved teacher actions, student activities, situations, etc. that, according to the teacher, had the intended student effects. By thinking of and sharing these events, teachers were stimulated to reveal their expertise, views and ideas, which offered insights into their frame of reference that might be useful when they taught the unit (function a, b).

To make it easier for teachers to define their learning goals, the coach introduced a four-step approach (function c). This approach started by focusing on what the intended effects on students were and what students needed to do according to the activities in the unit to achieve these effects (first and second steps). Then teachers defined what they needed to do to support and guide this learning process of the students and what they needed to develop to be able to perform these teacher actions (third and fourth steps).

Participants

Teachers were motivated to participate in the professional development programme by recounting their personal interest in the curriculum innovation, describing the problems in their school situation that could be solved by teaching the context-based units, and taking advantage of the chance to work together and share experiences with teachers from other schools. In addition, they were motivated by the opportunity to contribute to and advise about the curriculum innovation. They also received remuneration and the offer of intensive coaching and professional development to prepare for the upcoming curriculum innovation.

The final group comprised seven teachers with respectively half, two and a half, three, three, five, eight, and ten years of experience of teaching in secondary schools. The teachers came from seven different schools. One teacher had taught a previous version of the particular context-based chemistry unit on two previous occasions. She did not participate in the problem analysis phase in the professional development programme. Her processes in sense-making could not be fully analysed, so these data were omitted from this chapter. The other teachers did not have any experience of teaching context-based chemistry units. The teachers all taught the same conventional curriculum, which was the standardised chemistry curriculum in the Netherlands (2010).

The coach was one of the pioneers in the early days of this particular curriculum innovation. He was one of the first designers of context-based chemistry units in the Netherlands and he taught these units at his own school. Before participating in this

Teachers*	School	Years of Experience		
		Conventional curriculum	Context-based education	Teaching the particular unit in this course
Tom	School A	3	0	0
Eva	School B	5	0	0
Patricia	School C	2 1/2	0	0
Jason	School D	1/2	0	0
Julia	School E	3	0	0
Rick	School F	8	0	0
Kate	School G	10	3	2

Table 1 Characteristics of teachers who participated in the case study
** all pseudonyms*

study, the coach gained two years of experience in coaching teachers to teach these and other context-based chemistry units when the curriculum innovation was implemented on a bigger scale. The researcher (author of this thesis) guided the workshop about macro-micro thinking and observed the activities. She was a PhD student with two years' experience of teaching in secondary schools.

The students were 14 or 15 years old. They were in a secondary school class and had similar previous educational backgrounds. They had not participated in context-based chemistry education before.

Materials

In the workshop (in the first meeting), scientific articles were provided together with pictures of structures and properties of bamboo on different scales. A presentation was given about products made from bamboo. Teachers used the pictures to construct a conceptual scheme of the structures and properties of bamboo.

The programme required teachers to teach a unit on macro-micro thinking. This unit involved setting the context, during which project teams of students and the teacher as a senior member were assigned the task of developing a composite material with which an artist could make artefacts. The desired properties of the composite material were strength and compactness, as it had to travel around in an exhibition, and it should not absorb grease from the fingers of visitors. In a product development procedure, consisting of two cycles of gaining information, developing, testing and improving the product, the project teams needed to know more about the structure–property relations of several materials to explain and argue for their design decisions. The project teams had to carry out general research activities, such as reading literature and conducting experiments, in order to find out more information about materials such as clay, paper and gypsum. They then formulated the results in terms of structure-property relations, such as: ‘IF a material consists of parallel-orientated fibres, THEN the material has a high tensile strength’.

Data collection

Data were collected that gave insight into teachers' personal frame of reference and their process of sense-making on teaching the context-based chemistry unit. The focus was on teachers' success in (i) setting the context in class, (ii) performing the teaching role and (iii) teaching the new content of macro-meso-micro thinking in structure-property relations (Figure 3).

Data instruments consisted of mind-maps of the teachers’ associations with context-based chemistry education; video recordings of meetings; an interview with each teacher at the interface of preparation and discussion; teachers’ logs during instructions; recordings of lessons during instruction; the lesson materials, lesson plans and student assessments which were designed or adapted.

Because the specific focus of data analysis was on teachers' sense-making of (iii) teaching the new content as a result of the additional phase of problem analysis in the preparation phase, a very important data source was the interview with each teacher at the interface of the preparation and instruction phase. During the instruction phase, the first or second lesson of each teacher was recorded. After the lesson, the teacher and researcher analysed and discussed his/her video to stimulate teachers' sharing of expertise in a video recall procedure (Welsh and Dickson, 2005). During this video recall procedure, the teacher was interviewed about his/her experiences, his/her new understandings and insights during the problem analysis and preparation phase and his/her plans for instructing the unit in class during the next lessons, and specifically on teaching the new content of macro-micro thinking in structure-property relations.

Data analysis

Because the interrelated nature of the three aspects of (i) the context-setting, (ii) the teacher's role and (iii) the content in context-based chemistry education, data analysis was focused on describing teachers' sense-making during the programme in all three aspects simultaneously. To analyse teachers' personal frame of reference and sense-making of teaching context-based chemistry education, video recordings of the meetings and the interview at the interface of preparation and instruction were selected as primary data sources. In the video recordings and interview teachers revealed their frame of reference for teaching the conventional curriculum and their perspectives on teaching context-based chemistry curriculum. The data sources of every single teacher were selected, combined and analysed in a qualitative way and in chronological order. From these data sources, quotations were selected and clustered in terms of the new aspects in teaching context-based education (i-iii) as a coding scheme. The quotations in category (iii) were categorised in more detail in terms of: 1. relating structures to properties in a material; 2. zooming into structures to determine substructures in a material; 3. explaining properties by describing the interacting substructures in a material.

An inner-case analysis (Miles and Huberman, 1994) was conducted, in which teachers' process of sense-making in (i) setting the context, (ii) performing the teaching role, and (iii) teaching the new content was classified by thick descriptions based on the categorised quotations. The process was then interpreted as 'assimilation', 'association', 'toleration' and 'distantiation'. Other secondary data sources, such as teachers' mind-maps, lesson plans, students' assessments, lesson material, teachers' logs, and written reflections, were used to interpret information from quotations in the primary data sources.

The interpretations were validated in a peer review procedure by the author of this thesis and a second researcher. The second researcher interpreted the coded and clustered quotations together with the thick descriptions in the same categories as described above. It turned out that two groups of clustered quotations could be interpreted either as assimilation or accommodation. However, this difference in interpretation would not change the overall results about the sense-making process of those teachers.

Results

Because of the interrelated nature of the three aspects of (i) context-setting, (ii) teacher's role and (iii) content in context-based education, first the results of teachers' sense-making are described chronologically according to the phases of the professional development programme. Then the results of teachers' sense-making in teaching the content of macro-micro thinking in structure-property relations during the programme are described in more detail in terms of the described categories (1 to 3). As an example of the results of every single teacher's sense-making in teaching context-based education, the results of teacher Tom will be described in detail and presented according to Luttenberg's model (Figure 5) in four moments in time (see Figure 4) using data accordingly: A during the initial phase, B after the phase of problem analysis, C at the interface of the preparation and instruction phase, D during the reflection phase. An overview of the results of the other teachers is then provided (Figure 6). These results are further elaborated, clarified and illustrated.

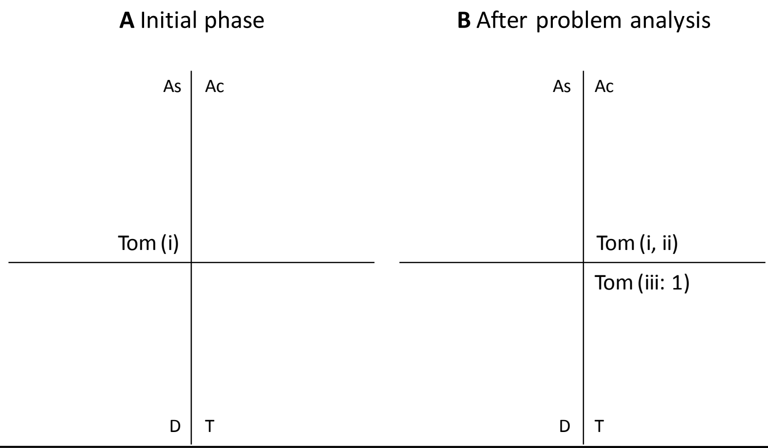
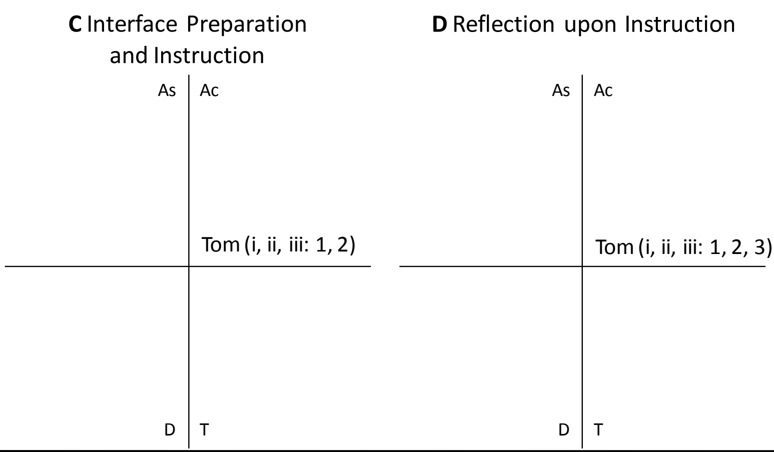


Figure 5 Results of Tom's sense-making of the new aspects of teaching a context-based unit. His sense-making of (iii) teaching macro-micro thinking is categorised as:
1. relating structures to properties in a material;
2. zooming into the structures to determine substructures in a material;
3. explaining properties by describing the interacting substructures in a material.

The case of Tom

Tom was a chemistry teacher in lower secondary education and had three years of experience. Before working as a teacher he worked in adult education and had a PhD in mass spectrometry. He said he had no experience of teaching context-based education, but when triangulating this with his mind-map he demonstrated some understanding regarding the aspect of (i) context-setting by associating context-based education with collaborative learning in project teams. In the first meeting he reported his deepening personal understanding about constructing theory from experiments and research skills. He revealed an understanding about theoretical models and scientific literature about student learning and used this to gain understanding about events in his and other classes. He was therefore assumed to have assimilated context-setting in his personal frame of reference. This was represented in Figure 5A as 'Tom (i)' in the 'Assimilation' quadrant. Tom's motivation to join the programme was that he liked the unit when he read it and wanted to see how students responded to this method of teaching.

In the second meeting, Tom said he had decided to plan a lesson about making ice cream, because the theme in his regular lessons was 'water'. He assigned the students to project teams to develop ice cream with certain quality criteria and properties. He emphasised that to develop the best ice cream, students needed to learn how to perform general research activities, such as lab work, designing experiments, reading literature, presenting results, and so forth. He demanded that



the students should acquire adequate research skills to test the quality of ice cream. Tom observed however that he never gave 'open' assignments. He was surprised that students shared his insecurity during the lessons. He reported in his reflection on this lesson that in class he had realised that he did not know what learning effect he wanted to achieve for the students.

These data during the phase of problem analysis suggested that Tom made sense of (i) the context-setting, (ii) the teacher's role, and (iii) the new content of macro-micro thinking in structure-property relations (Figure 5B). Tom continued to assimilate his abilities as a PhD researcher with teaching general research activities. He also accommodated his personal frame of reference regarding teaching problem-solving procedures in product development and managing project teams in class. Tom accommodated his role as a teacher and his skills in using pedagogical approaches with this 'open' assignment. Although he recognised and assimilated the aspects of (i) setting the context in class and (ii) performing the new teacher's role, he only tolerated (iii) the new content of macro-micro thinking in structure-property relations. He expressed to know, there was something about structures of ice cream and the properties concerning the quality (category 1 in teaching macro-micro thinking). He realised however that he did not know what student effect he wanted to achieve in the lesson. This is presented in Figure 5B as 'Tom (iii:1).

In the next phase when Tom prepared to teach the unit, he demonstrated accommodation of the aspects even further regarding (i) the context-setting and (ii) performing the new teacher's role (Figure 5C). For example in the interview, Tom described how he compared the project teams in class to achieve the best student effects. Tom planned to emphasise to the students that the intended learning effect was that they should learn how to do research and expand their research skills. He explained in the interview that he wanted to assess the students by letting the project teams make research posters. He said that students needed to show on the poster that there were several ways to solve the problem in product development. He was planning to organise a symposium so students could learn from each other's results and value the content of the posters.

Tom accommodated his frame of reference regarding (ii) the new teacher's role by using different pedagogical approaches compared with his regular lessons. During the recorded lesson, he instructed the students to do the activities in the unit independently, and when they had questions they could ask him. In the interview, he said that he monitored the learning of the students by collecting their work in a group folder. He explained that he unnoticed checked the results of their work when students called him to ask a question. In the interview, he argued that context-based chemistry education was very personal compared with conventional plenary lessons, and a very good way to differentiate between students. He started every lesson with a total overview of the activities in the unit and ended the lesson with a short summary.

In the reflection phase (Figure 5D), Tom demonstrated in explaining his reflections to accommodate (ii) the new teacher's role, which involved keeping overview about students performing activities during the lessons and supporting students to structure new knowledge on the basis of their existing knowledge. He experienced that context-based education requires a totally different way of assessing students. He suggested that it involved a shift from assessing facts and conceptual knowledge to assessing and monitoring procedural knowledge, group processes and products.

He explained how he managed project teams in class in a very structured way and how he used the roles of students within the teams to give instructions to the project teams. He related the roles of the students within the project teams to his knowledge of different learning styles of students and ways of collaborative learning. He understood that a teacher needs a broad perspective on solving the problem in product development in order to anticipate students' questions well in advance.

In the second reflection meeting, Tom added that in the unit the macro-micro thinking and the problem-solving aspect were the main learning effects for students. He reported to feel especially satisfied about managing the project teams. In his opinion, his role as a teacher changed from controlling the learning towards keeping an overview of the activities and monitoring the learning of the students. Overall he expressed positive feelings about teaching the unit.

Tom's sense-making of teaching macro-micro thinking in structure-property relations

Tom's sense-making in (iii) teaching the new content of macro-micro thinking in structure-property relations (Figure 3) was described more specifically in the categories (1 to 3). During the phase of problem analysis, Tom was able to plan a lesson that fitted into his regular lessons about 'water'. He only tolerated the new content at this stage of the professional development programme. This was represented is Figure 5B as 'Tom (iii:1)'.

He asked students to look closely at the structure of ice cream to assess the quality, but he did not know what students needed to find. He reflected in the second meeting that he needed the students' results of the assignment on making ice-cream to think about what he wanted to achieve. When he shared his uncertainty with the students, he noticed that they became uncertain as well.

He explained this experience as showing that the students were not used to open assignments. He showed his insecurity by concluding that, as a teacher, he did not give these open assignments very often and that students were not able to handle such questions. He also said that the lesson material he had decided to use did not provide support. His learning goal for teaching the unit was to decide what effects he wanted that students should achieve.

In the interview at the interface of preparation for and teaching of the unit, Tom demonstrated that he had accommodated the new content and did not feel any stress (Figure 5C: 'Tom (iii:1,2)'). He explained that he used macro-micro thinking in his lessons by instructing students to look at structures and properties on the macro level and relate them to structures on micro- or meso-levels. He wanted the students to use words such as macro, meso, micro, structure and property in the right way, instead of making the macro-micro thinking explicit. In the light of his understanding about student learning, he argued that every student has a different way of thinking. He reported that, during preparation, he shifted his understanding of structures as purely chemical structures of atoms, molecules and chemical bonding towards a broader perspective .

In the reflection meetings he confirmed what he reported in the interview and used additional examples from his experiences of teaching the unit (see Figure 5D). To his understanding of macro-micro thinking he added that problem-solving using macro-micro thinking to explain and predict properties was the main learning effect for students. In this, he showed that he fitted macro-micro thinking in structure-property relations to his frame of reference, which was represented as 'Tom (iii:1,2,3)'. Tom reported that the only way one could teach context-based education was if the teacher had comprehensive knowledge about the content of the unit.

Summary of the results of the other teachers

In Figure 6, the results are summarised for all teachers. The findings show that in the initial assignment and meetings all teachers demonstrated ideas and understanding in their personal frame of reference that suited the aspect of (i) context-setting in the frame of reference of teaching context-based chemistry education. This was not the case for the aspects of (ii) the new teacher's role and (iii) the new content. Some remarkable findings in terms of teachers' sense-making as represented in Figure 6 will be elaborated.

As regards teachers' problem analysis it was remarkable that although teachers were asked only to focus on teaching macro-micro thinking in structure-property relations, they automatically assimilated other aspects and abilities that they recognised from their personal frame of reference (see Figure 6B). For example, Patricia assimilated her way of organising and planning lessons in detail by keeping an overview of planning and activities. She accommodated her frame of reference by organising a different balance between student- and teacher-centred instruction compared with her conventional teaching. Rick created a common knowledge base for all students at the start of every lesson, as he said 'he always did'. He recognised and was aware that it was important to create such a common knowledge base, and assimilated this when teaching the context-based chemistry unit.

When preparing and teaching the unit, teachers kept on assimilating and accommodating aspects which they recognised from their personal frame of reference (Figure 6C). Assimilation and accommodation of (i) setting the context and (ii) performing the teaching role meant that teachers tried new pedagogical approaches to monitoring and assessing student learning, motivating students to take ownership of the problem-solving and gaining understanding of the relation between context-setting and content. Most teachers focused on managing project teams, creating a different balance in student- and teacher-centred instruction, and keeping an overview about organising and planning activities. Rick, Julia, Patricia and Tom monitored student learning by collecting work in a group folder and let students keep a log to evaluate the group processes. Rick also managed the project teams in such a way that they needed to collaborate to find a solution to the problem of developing a product with the desired properties. Julia focused on how she could motivate and guide the students when they worked in project teams.

As demonstrated in Figure 6, Eva did not accommodate any aspect of context-based education. She only assimilated the aspects she recognised from her conventional teaching, and did not actively try to accommodate unfamiliar aspects of context-based chemistry education. For example, she explained that she had an assistant who prepared the research activities for the students and taught them. As a teacher she could distantiate herself from teaching research activities and skills. Eva also reported that she had problems understanding the content of the unit. She said that the problem analysis phase was helpful in preparing her and the students for macro-micro thinking and working in project teams. She was, however, very focused on the process in the classroom and assimilated the teacher's role when teaching the context-based chemistry lessons and unit. Eva reported that her role in class was not very different from her usual role.

In the reflection phase, except for Eva, teachers assimilated and accommodated the aspects of (i) context-setting and (ii) the new teaching role that they recognised from their personal frame of reference at the start of the programme. Jason especially made huge progress in accommodating the new aspects. Teachers were happy with their achievements, and they all wanted to teach one or more context-based chemistry units in the next school year.

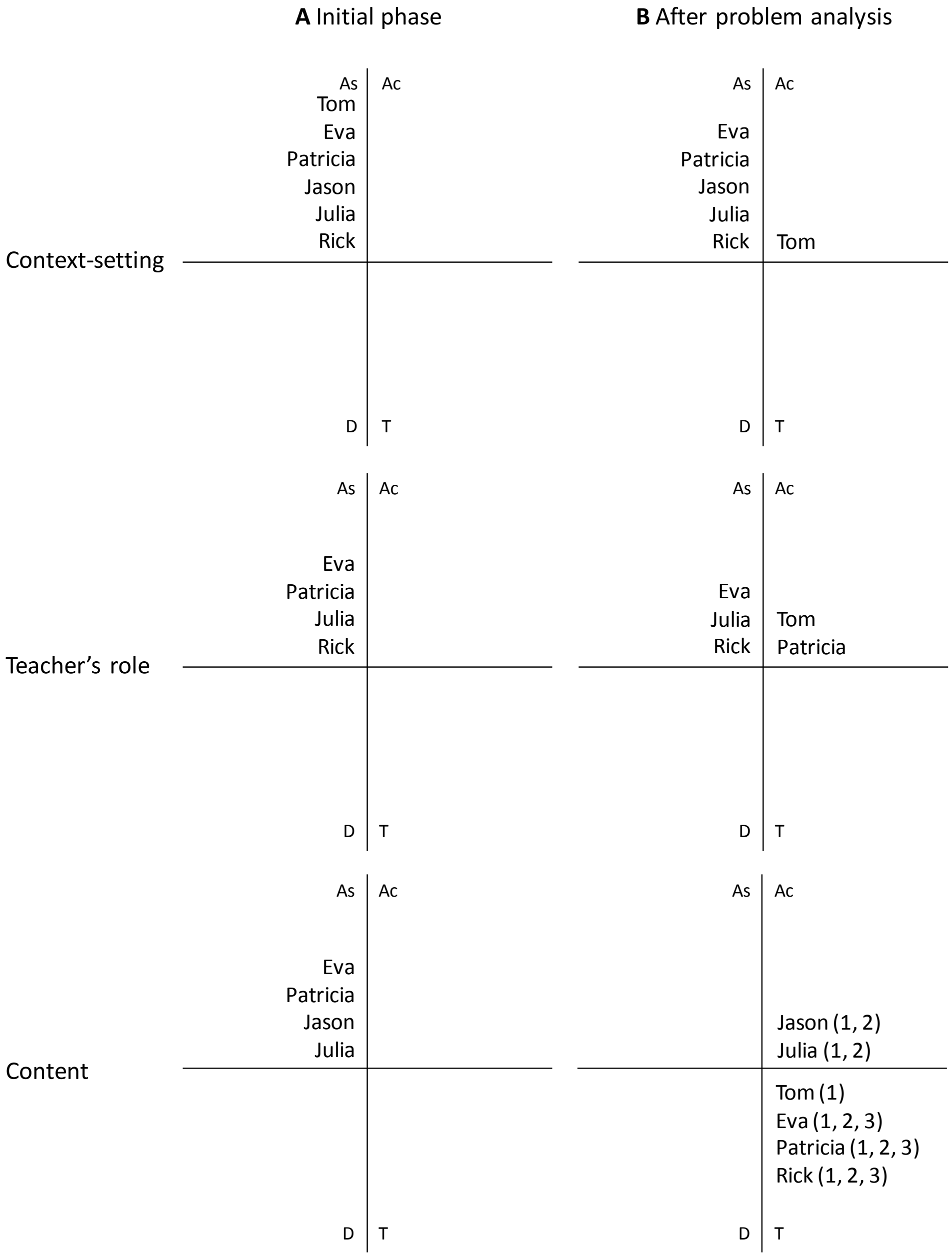


Figure 6 Overview the results of teachers' sense-making in the new aspects in teaching a context-based unit. Teachers' sense-making in macro-micro thinking is specified into the categories:
1. Relating structures to properties in a material;
2. Zooming into the structures to determine substructures in a material;
3. Explaining properties by describing the interacting sub-structures in a material.

C Interface Preparation and Instruction

As	Ac
Patricia Jason	Tom Julia Rick
Eva	
D	T

As	Ac
Eva	Tom Patricia Julia Rick
D	T

As	Ac
	Tom (2) Patricia (1, 2) Rick (1, 2, 3)
	Jason (1, 2, 3) Julia (1, 2, 3) Eva (1, 2, 3)
D	T

D Reflection upon Instruction

As	Ac
	Tom Jason Julia Rick
Eva	Patricia
D	T

As	Ac
Eva	Tom Patricia Jason Julia Rick
D	T

As	Ac
	Tom (1, 2, 3) Patricia (1, 2, 3) Jason (1, 2, 3) Julia (1,2, 3) Rick (1, 2, 3)
	Eva (1, 2, 3)
D	T

Other teachers' sense-making of teaching macro-micro thinking in structure-property relations

In the initial phase, several teachers said they had heard of macro-micro thinking in structure-property relations (Figure 6A) but only Jason and Julia demonstrated any understanding of how to teach macro-micro thinking in structure-property relations in context-based education.

In the problem analysis phase, Eva, Patricia and Rick copied in detail the teaching strategies from the workshop to teach macro-micro thinking in structure-property relations to their students. This suggested that they were prepared to teach macro-micro thinking but it did not fit into their personal frame of reference about teaching the conventional chemistry curriculum (Figure 6B). Jason and Julia tried to integrate macro-micro thinking in structure-property relations into their regular lessons, as requested. This was interpreted as accommodation. The main learning goals that they formulated for teaching the unit involved zooming into the structure of materials (2) and defining and naming the structures and properties in the conceptual scheme (1).

Jason tried to teach macro-micro thinking in one of his regular lessons about reaction equations, because he said he could not deviate from the school programme. Although he thought he had integrated the new content in his regular lesson, however, he reported in the second meeting that the students saw macro-micro thinking as a totally different subject. This could be interpreted as accommodation but it could also be interpreted as toleration, because the students revealed that Jason was teaching macro-micro thinking as a different subject in the lesson.

Julia tried very hard to implement macro-micro thinking in structure-property relations into her regular lessons about phase transitions in matter. She reported in the second meeting that she had left out the meso-level because she could not think of structures and properties of matter in the different phases. She noticed that students were not able to describe properties and structures by themselves. She needed to help them a lot by using examples and metaphors. In the light of her experience she concluded that when students understood macro-micro thinking in structure-property relations they could also better understand the theory about phase transitions in matter than when the conventional curriculum was taught.

In the interviews at the interface of preparation and instruction, teachers did not reveal their sense-making on teaching macro-micro thinking so much (Figure 6C). They were busy with other aspects of teaching the unit, such as managing project teams, organising experiments in class, keeping an overview on activities, etc. Although teachers were not aware of their sense-making in teaching macro-micro thinking in structure-property relations at this stage in the programme, indirectly they still made sense of the new content. For example, Jason and Julia, who were accommodating the new content during problem analysis, were so busy with the other aspects that they reported that macro-micro thinking was not the main student effect they wishes to achieve. This was interpreted as a reversion to toleration of the new content. They did not, however, reveal the feelings of stress and demonstrated coping strategies that could be expected (Chapter 3) when teachers do not have sufficient expertise in teaching content. At this stage, Patricia and Rick did accommodate teaching the new content.

Contrary to what they reported in the interview, teachers reported in the first reflection meeting at the end of the programme that macro-micro thinking in structure-property relations was the most important student effect to achieve when teaching the unit. Except for Eva, the teachers showed a full understanding of macro-micro thinking as described in categories 1 to 3. They also appeared to understand the similarities and differences regarding teaching macro-micro thinking in the conventional curriculum and the context-based curriculum. That being so, during the professional development programme teachers accommodated the aspect of macro-micro thinking in structure-property relations in their personal frame of reference.

Discussion

This study aimed to evaluate an adapted framework for teachers' professional development to help them to accommodate the new aspects in context-based chemistry education of (i) setting a context in class, (ii) performing the new teacher's role, and (iii) teaching the new content. The focus of this study was to obtain an insight into the influence of the additional phase of problem analysis on teachers' sense-making on teaching the new content. The results showed that the professional development programme led to teachers' successful accommodation of the three aspects. The problem analysis phase led to the teachers' toleration and accommodation of macro-micro thinking in structure-property relations. The influence of the additional phase on teachers' sense-making and implications for designing professional development programmes are further discussed.

The adaptations in the framework for teacher's professional development (Chapter 3; Dolfing et al., 2011; Stolk et al., 2012) provided teachers with an adequate problem analysis of teaching the content of macro-micro thinking in structure-property relations at the beginning of the programme (Handelzalts, 2009; Voogt et al., 2011). Five out of six teachers accommodated the new content at the end of the professional development programme. Teachers did not demonstrate similar stress at the interface of preparation and instruction to that demonstrated in Chapter 3 (Dolfing et al. 2011).

In this study, teachers demonstrated different combinations of the four types of sense-making within one teacher (Ketelaar et al., 2012; Luttenberg et al., 2011). Teacher's sense-making of the new content occurred mostly through processes of toleration followed by accommodation. On the basis of this research, however, one could add that when teachers are confronted with a curriculum innovation they have a tendency first to assimilate the aspects they recognise from their own frame of reference about teaching the conventional curriculum, as shown in similar current studies among biology teachers (Wieringa, 2012). Even when they were required to focus on integrating the content in their own teaching, they first focused on assimilating recognisable aspects in performing the new teaching role or setting the context in class.

As the process of sense-making is considered to be an active cognitive and emotional process in which a person attempts to fit the new information into existing expertise and beliefs (Coburn, 2004; Coburn, 2005; Spillane et al., 2002; van Veen and Lasky, 2005), the process of distantiation could largely be related to teachers' stress and coping strategies, as found in earlier studies (Brown et al., 2002; Dolfing et al., 2011; Thompson, 2005). The additional phase provides teachers with an adequate problem analysis for teaching the new content, and prevents the stress and strategies that could hinder their continuous and sustainable professional development in context-based chemistry education (Armour and Yelling, 2004).

There seems to be a balance to be struck between focusing on the differences and focusing on the similarities in teachers' personal frame of reference and the frame of reference for teaching the new curriculum. Focusing on the similarities could stimulate teachers to focus on assimilation of these recognisable aspects and abilities in their teaching. Focusing on the differences, however, could stimulate teachers to distantiate or tolerate the new aspects of teaching the context-based unit. A good balance of the two results in teachers' toleration and accommodation of the new content in curriculum innovations.

As teachers make sense of the curriculum innovation in the light of their own expertise, their own school situation and the conventional curriculum (Ketelaar et al., 2012; Spillane et al., 2002), sense-making in teaching the new content could be influenced by many factors in group dynamics (Forsyth, 2010): teachers' personal frame of reference in teaching the conventional curriculum, the school situation and the professional development programme. These factors also include social interaction among teachers in the group, the role of the coach and the sequence of activities.

The interaction with students in class is essential in terms of teachers' sense-making. By interacting with students, teachers project their sense-making onto the students and formulate expectations. When these expectations do not match the actual student effects, teachers become motivated to gain deeper understanding about the new content of macro-micro thinking in structure-property relations. Teachers use the interaction with students to formulate their own learning goals. The additional phase provides teachers with the opportunity to interact with students and focus only on the new content, without the hassle of the other new aspects in context -based education and practical issues (Coenders, 2010; Handelzalts, 2009; Voogt et al., 2011).

These conclusions lead to the following recommendations for designing a similar professional development programme to support teachers in curriculum innovation. First, the main new aspects of teaching the unit need to be determined, with special attention to the new content, as it is a prerequisite for thinking about teaching strategies and pedagogical approaches (Van Driel et al., 1998). Before teachers prepare to teach the unit in class, they should orientate themselves to these new aspects. An adequate phase of problem analysis requires all the functions described in by Stolk et al. (2012) to be fulfilled in relation to the new aspects. Second, in this phase a balanced focus needs to be created regarding the differences and similarities between aspects in the conventional and the new curriculum. Third, the activities in the phase of problem analysis need a hands-on activity that teachers can copy to use directly in class, so they experience for themselves how to teach the new aspect to their students. Linking student learning effects to teachers' own learning goals is a crucial step in stimulating teachers' development (Chapter 3; Dolfing et al., 2011) and sense-making regarding the new curriculum.

The validity of these recommendations is subject to several limitations. Our adaptation of the framework was carried out in the initial stage of implementing a curriculum innovation. Whether the framework is applicable more generally in professional development programmes requires further investigation. The results are based on six chemistry teachers only. These teachers are unlikely to be representative for the majority of chemistry teachers in the Netherlands (Van Driel, Bulte and Verloop, 2005). Although the data analysis primarily focused on teachers' sense-making of (iii) the new content, it was not possible to separate this aspect from the aspects of (ii) performing the new teacher’s role and (i) setting the context in class (Meijer et al., 2009; Prins et al., 2008; Westbroek, 2005). In context-based chemistry units the new teacher’s role and the new content are determined by the specific context-setting. Consequently and similar to teachers’ development of expertise in these three aspects (Chapter 3; Dolfing et al., 2011), teachers' sense-making of the new content could not be studied separately from sense-making in performing the new teacher’s role and setting the new context in class. In addition, the problem analysis phase could only be evaluated in the light of the whole professional development programme.

Further research is needed to evaluate the applicability of the framework of the professional development programme to other science domains (e.g. biology, physics) and other kinds of innovations (e.g. inquiry-based, competence-based). In addition, further research could give insights into how to balance the bottom-up approach of creating an atmosphere which respects teachers' professional identity and ownership of their teaching and the top-down approach of stimulating teachers to come out of their comfort zone and experiment in their classrooms to implement a curriculum innovation.

Acknowledgements

The authors would like to thank the teachers and the coach for their effort and support and for participating in this study.

Appendix

Table 2 The professional development programme

<table>
<tr><th>Phase</th><th>Functions</th><th>Activities</th></tr>
<tr><td>Initial</td><td>a. Connect to teachers’ views on context-based education
b. Reveal ‘useful’ teachers’ initial domain-specific expertise</td><td>Assignment to make a mind-map, lesson plan and student assessment related to their initial views of context-based education (function a, b)</td></tr>
<tr><td rowspan="2">Problem analysis</td><td rowspan="2">c. Let teachers discover differences and similarities among their views on teaching the conventional content and teaching macro-micro thinking in structure-property relations
d. Let teachers explore strategies for teaching the macro-micro thinking in structure-property relations
e. Provide the opportunity for teachers to define their learning goals
f. Provide the opportunity to apply the domain-specific expertise in practice
g. Give teachers the opportunity to reflect on their teaching and learning experiences
h. Examine teachers’ development by creating the opportunity for teachers to produce a product
i. Evaluate teachers’ development</td><td>1. Introduction to teaching of the new content
• Getting acquainted with each other
• The coach and researcher present the task and purpose of the programme which the teachers should achieve, followed by clarifying questions and discussion to get agreement and consensus (function c)
• Performing a workshop about the content of macro-micro thinking (function c), followed by making lesson plans for one lesson about this content (function d, h)
• Share prior experiences of teachers in teaching context-based units (function a, b)
Homework:
• Instructing a lesson about the new content in teachers’ own school situation (function f)
• Thinking of ‘successful events’ in teachers’ experience when teaching the conventional curriculum (function a, b)</td></tr>
<tr><td>2. Definition of teachers’ learning goals
• Teachers discuss and reflect upon their teaching strategies and student effects of teaching the new content of macro-micro thinking (function g)
• Teachers share their ‘successful events’ and report them on a joint poster (function b, d)
• Teachers following the four-step approach (function d, e, i):
1. Define intended student effects
2. Relate intended student activities to the effects
3. Explore teachers’ actions to achieve the intended student effects
4. Define teachers’ learning goals in accordance
Homework:
• Optional: Improve and instruct the improved lessons about the new content (function g, h)
• Study the unit, student activities and effects in detail, to teach in teachers’ own school situation (function d)</td></tr>
</table>

Problem analysis		**3. Performing collaborative learning approaches** • The coach introduces various collaborative learning approaches that could be applied when instructing the unit (function c) • Making lesson plans for one lesson about an actual issue in the conventional curriculum using one or more collaborative learning approaches (managing project teams)(function d) Homework: • Instruct the lessons including the collaborative learning approaches in teachers' own school situation (function f) • Adapt the unit for teachers' own school situation using the new expertise teachers acquired by instructing the lessons (function d, h)
Preparation of the unit	c. Let teachers discover differences and similarities among their views on context-based education and the context-based unit d. Let teachers explore strategies for teaching the context-based unit, give examples, and present conditions for use e. Provide the opportunity for teachers to define their learning goals	**4. Planning to instruct the unit** • Sharing experiences of and reflecting on instructing the lessons including collaborative learning approaches (function g) • Reporting and discussing the adaptations of the unit by following a collaborative learning approach (function d) • Elaborating in a discussion the intended teaching actions to achieve the intended student effects and teachers' learning goals (function d, e) *Homework:* • Making lesson plans including teachers' learning goals and a mid-term student assessment (function d, e, h)
		5. Planning • Reporting and discussing the lesson plans and student assessments (function d, e) *Homework:* • Making definitive versions of the unit, lesson plans and students' assessments (function d, e, h)

Table 2 (continued)

Instruction of the unit & Reflection upon instruction	f. Provide the opportunity to apply the domain-specific expertise in practice g. Give teachers the opportunity to reflect on their teaching and learning experiences h. Examine teachers' development by creating the opportunity for teachers to produce a product i. Evaluate teachers' development	Instructing first part of the unit in teachers' own school situation (function f)
		6. Mid-term evaluation and reflection • Sharing experiences and discussing the instruction of the lessons, lesson plans and adapted unit based on the outcomes of the mid-term student assessment (function g, h) • Sharing and discussing individual problems experienced during instruction (function g) • Preparing the lesson plans and the final student assessment for the second part of the instruction (function h) *Homework:* • Final lesson plans and student assessment (function h)
		Instructing second part of the unit in teachers' own school situation (function f)
		7. Evaluation and Reflection • Expressing experiences, emotions and feeling during instructing the unit (function i) • Sharing and discussing the intended student activities and student effects of the unit, the problems experienced during instruction, teachers' development, etc. (function g, i)
		8. Reflection and Incorporation • Reflecting on teaching the unit, participation in the programme, incorporating the expanded expertise by adapting strategies for teaching the unit on a subsequent occasion (function f, g, h, i)

Table 2 (continued)

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Chapter 1 Design issues	The collaborative setting	The sequence of activities within the framework	The development of intended domain-specific expertise
Explorative study			**Chapter 2** Determining the intended domain-specific expertise
First case study	**Chapter 4** Exploring patterns in group dynamics that influence teachers' development of domain-specific expertise		**Chapter 3** Describing the domain-specific expertise that teachers develop during the programme
Second case study		**Chapter 5** Planning a sequence of activities within the framework to support teachers' development	
Chapter 6 Understandings for designing	Strategies in composing and coordinating collaborative settings to support teachers' development	Strategies in planning the activities to support teachers' development	Description of the intended domain-specific expertise

Chapter 6

Conclusions and Reflection

Introduction

This thesis reports on a research project, to gain insight into how to design a professional development programme, to support teachers in the curriculum innovation of context-based chemistry education. The aim of this research project was to gain more understanding of the learning processes of experienced teachers in collaborative settings, as a strategy to implement such a curriculum innovation. This chapter presents a short overview of this research project, followed by general conclusions. It also describes a reflection on the decisions within, and the knowledge claim of this research project. The chapter ends with implications of the results, recommendations for educational designers and teacher educators, and an outlook for further research. The central research question of this research project was:

What strategies, implemented in a professional development programme, support teachers in developing domain-specific expertise in teaching context-based chemistry education?

Three design issues were considered to be important for designing a professional development programme. The first issue involved the domain-specific expertise that teachers need and develop when teaching context-based chemistry education. The second issue considered the influence of group dynamics in the collaborative setting, on the development of teachers' domain-specific expertise during the professional development programme. The third issue considered the framework and sequence of activities to plan within the programme, to support teachers in developing domain-specific expertise. Based on these issues, four empirical studies were conducted. The conclusions of these studies are summarized in the next section.

Research overview and general conclusions

In order to answer the central research question, a short overview of the project is presented. This project was divided into four studies. The first study was an explorative study, to determine the new domain-specific expertise teachers need to develop to teach context-based chemistry units (Chapter 2). In this study, teachers pioneered the curriculum innovation and taught the context-based chemistry units. Based on what these teachers experienced, the new additional domain-specific expertise was determined and described. The following research question was answered:

What new domain-specific expertise do experienced chemistry teachers need to acquire in order to teach an innovative context-based unit about macro-micro thinking, using meso-levels in structure-property relations?

This study resulted in the description of the domain-specific expertise, in terms of seven abilities that teachers need to teach a context-based chemistry unit. For the second study, these abilities were categorized in terms of: (i) setting the context in class of project teams that are assigned to solve a problem in product development; (ii) performing the new teacher's role as a senior member of the project teams; and (iii) teaching the new content of macro-micro thinking in structure-property relations.

The second study focused on the development of the domain-specific expertise when teachers participate in a professional development programme (Chapter 3). The study involved a case study approach, in which teachers, guided by a coach, participated in a collaborative setting to teach a context-based chemistry unit. This case study provided an answer to the following research question:

What domain-specific expertise do teachers develop when they teach a context-based chemistry unit about macro–micro thinking in structure–property relations in a collaborative setting?

The results of this study showed that teachers developed new domain-specific expertise when they prepared the unit collaboratively, to instruct in their own school situation. However, they hardly expanded this newly developed expertise during instruction and reflection. The professional development programme did not provide teachers with an adequate problem analysis on teaching the new content of macro-micro thinking in structure-property relations during the preparation phase. This hindered teachers in expanding their domain-specific expertise.

Based on the results of the second study, the focus of this research project was directed towards the preparation phase in the professional development programme. The third study focused on the collaborative setting in which teachers participated, and the fourth study focused on the sequence of activities that was planned in the preparation phase.

The third study was conducted on the data of the second study. The focus of this study was to explain teachers' (lack of) development of domain-specific expertise in a collaborative setting, as described in the second study, from the perspective of group dynamics (Chapter 4). This study aimed at identifying patterns in group dynamics, that influence the development of domain-specific expertise, when teachers participate in a collaborative setting. This study provided more insight into why and how collaboration enhances teacher learning, and how to improve this collaboration in professional development programmes, to support teachers in teaching context-based chemistry units, and to develop the intended domain-specific expertise. This study provided an answer to the following research question:

What patterns in the group dynamics of collaborating teachers can be identified that influence teachers' development of the domain-specific expertise that is required for teaching a context-based unit?

Three patterns in group dynamics were identified that influenced teachers' development, regarding teachers' engagement, the roles of the group members, and coordination of the coach. Pattern I, 'Double group purpose', and Pattern II, 'Leadership of the coach towards sharing', influenced the development positively. The lack of teachers' development in teaching the new content was explained mostly by Pattern III, 'Hierarchy among the teachers', based on experience of teaching context-based units. The hierarchy and roles among the group members had a great influence on the social interaction and focus of the discussions, and thus on teachers' development of domain-specific expertise.

Based on the results described in the second study, the fourth study focused on planning a sequence of activities to improve teachers' sense-making, in teaching context-based chemistry units during the professional development programme (Chapter 5). This study focused particularly on providing teachers with adequate problem analysis, for teaching the new content of macro-micro thinking in structure-property relations. An additional phase and functions to achieve accordingly were added to the framework of professional development, as presented in Figure 2, presented in Chapter 1. This study provided insight into more general understanding about strategies for teachers' professional development in curriculum innovations, in which teachers were confronted with the frame of reference of teaching the new content. In this study, the following research question was answered:

To what extent does the sense-making process during the professional development programme, based on the adapted framework, result in teachers' accommodation of
-the specific context-setting in class,
-the performance of the new teacher's role, and especially,
-teaching of the new content in context-based chemistry education?

The results showed that the professional development programme did lead to teachers' accommodation of setting the context in class, performing a new teacher's role and teaching the new content. The additional phase of problem analysis did lead to the teachers' toleration and accommodation of macro-micro thinking in structure-property relations.

These studies led to the overall aim of this research project described in this thesis to provide more understanding of how to design a professional development programme, and find strategies concerning the three design issues of the programme; namely, the group dynamics in the collaborative setting, the activities to be planned within the framework, and the development of the intended domain-specific expertise. Design decisions concerning the issues of the collaborative setting, and the activities in the framework, can support teachers in developing expertise in teaching context-based chemistry education. Implementing strategies concerning group dynamics and the phases, activities and functions within a framework, support teachers in developing shared expertise in (i) setting the context in class, (ii) performing a new role, and especially in (iii) teaching the new content of macro-micro thinking in structure-property relations.

From the empirical studies described in Chapters 4 and 5, strategies could be retrieved to support teachers in developing domain-specific expertise in a collaborative setting, to teach a context-based chemistry unit. In the study described in Chapter 4, three patterns in group dynamics were found that could be used as strategies (See below, I–III) in the professional development programme. From the results described in Chapter 5, three other strategies (IV–VI) can be delineated to support teachers in developing domain-specific expertise in teaching the new content of macro-micro thinking in structure-property relations.

Strategies in group dynamics

I. Double two-way purpose: To engage teachers in discussions within the collaborative setting in order to develop domain-specific expertise in teaching context-based chemistry units, designers need to create a strategy of a 'double two-way purpose' for the group to participate: 1. They are facilitated to prepare themselves, with intensive guidance on the upcoming curriculum innovation; 2. They are assigned to advise the curriculum developers about the implementation of the curriculum in regular schools. The casting between the coach, as most experienced teacher, and the researcher, as least experienced teacher, maintains this 'double purpose'. This stimulates teachers' sharing of experiences and expertise during the discussions in the meetings, and so enhances their development of domain-specific expertise.

II. Leadership towards sharing: To create a respectful learner atmosphere, in which teachers are stimulated to develop new domain-specific expertise collaboratively in teaching the context-based unit, the coach needs to coordinate and direct the discussions towards sharing teachers' experiences in teaching the unit in their own classes. Then, teachers are approached as professionals and experts in their own school situation. By following up the instruction to let teachers share experiences by an instruction to use the experiences in group performances, teachers are prevented from criticizing each other's practice.

III. <u>Hierarchy:</u> To guide and direct discussions in the collaborative setting, it is useful that the coach makes the contributions of the more experienced teachers productive. However, the contributions to the discussions of the more experienced teachers are considered as more important than those of other teachers. Then, in the group, a hierarchy develops among the teachers, based on their prior experience in teaching context-based units. Consequently, the focus of the discussions is directed by the input of the more experienced teachers, and as such it influences the development of domain-specific expertise.

Strategies for planning activities

IV. <u>Phase of problem analysis:</u> To support teachers in teaching the new content, teachers need to conduct an adequate problem analysis on teaching the new content before they prepare to instruct the context-based chemistry unit. An adequate phase of problem analysis means that all functions described in the framework (Chapter 1, Figure 2) are fulfilled in relation to the new content.

V. <u>Iteration of preparation, instruction and reflection:</u> To achieve the functions to support teachers' problem analysis in teaching the new content, a sequence of activities needs to be planned regarding preparation, instruction and reflection on a lesson about the new content. The sequence of activities should provide teachers with an opportunity to get introduced to the frame of reference for the new content, and to become aware of their personal frame of reference on teaching the (new) content in the conventional curriculum. In this respect, a balance in focus needs to be created towards the differences and similarities between aspects in the conventional and the new curriculum. It is crucial to stimulate teachers to accommodate their personal frame of reference within the frame of reference for teaching the new content in their interaction with students.

VI. <u>Hands-on activity:</u> To stimulate teachers' development and sense-making towards teaching the new content of the new curriculum, the phase of problem analysis should involve a hands-on activity that teachers could use directly in class. As a result, teachers experience how they could teach the new content to their own students. This leads to teachers' toleration of teaching the new content as a first step towards accommodating their personal frame of reference towards teaching context-based chemistry education. In addition, linking student-learning effects to teachers' own learning goals is an important step in teachers' sense-making about the new content.

Reflection on the decisions and knowledge claim

During this research project several topics for discussion came up and decisions were made, when conducting the studies. These topics for discussion and decisions involve three main reflective questions. This section describes the reflection on this research project, according to these main questions.

When determining what domain-specific expertise teachers need to teach context -based chemistry education, first question was how to describe the intended domain-specific expertise. Issues arose concerning what a teacher's expertise is, what components it involves, and which construct and labels to use to describe teachers' expertise. To implement a curriculum innovation, it was important to distinguish which expertise was personal and which was common or shared among teachers (Verloop, Van Driel and Meijer, 2001). In addition, it was important to gain insight into what expertise was specific for the domain of teaching context-based chemistry units, compared to the domain of teaching the conventional curriculum. Different constructs were considered for use: e.g. Pedagogical Content Knowledge (PCK) (Abell, 2008; Kind, 2009); Knowledge and Competence (Eraut, 2007; Mulder, Weigel and Collins, 2007; Verloop et al., 2001; Westera, 2001); and Expertise (Ericsson, Charness, Feltovich and Hoffman, 2006; Ropo, 2004). It was noted that, in these studies, the different constructs involve specific subdimensions, categories and descriptions of components in teachers' expertise, as well as in specific studies concerning teachers' designing and implementing context-based (science) education (De Putter-Smits, Taconis, Jochems and Van Driel, 2012; Van der Zande, Waarlo, Brekelmans, Akkerman and Vermunt, 2010; Wieringa, Janssen and Van Driel, 2011). These constructs are often conceptualized according to the convenience of the particular study in which they are used. However, these conceptualizations also involve many similarities in components, definitions and labels. Consequently, for every single study the constructs need to be redefined in terms of categories and labels, to describe what is being investigated.

Owing to the early stage of the curriculum innovation for context-based chemistry education, it was unknown what expertise was new for teachers, and what was required to teach context-based chemistry education. In particular, expertise in setting the context in class was assumed to be new and needed to be integrated into teachers' expertise in implementing pedagogical approaches and teaching the content. Using the construct of domain-specific expertise, and defining it in general as 'the ability to perform successfully in a specific domain' (Ericsson et al., 2006) provided the opportunity to describe the required expertise without pre-assumptions, pre-defined categories, or associations about what expertise to find. In addition, the construct of expertise, as described in Chapter 2, gave insight into which components of expertise are involved, taking into account the repertoire and performance of the teacher in context-based education. However, it is, of course, no surprise that the abilities described in Chapter 2 involved expertise in using new pedagogical approaches, teaching the content, and performing the new teacher's role, since these are commonly described categories in teachers' expertise. Probably several other constructs could have been used to describe the results that were found in the empirical studies of this thesis.

The second main question was how this teacher expertise develops when the domain of practice changes, as in curriculum innovations. It is popular to say that teachers learn continuously through practice, because teaching is different every day. However, people tend to perform their usual practice, which is demonstrated by routine actions and low stress levels (Carlyle and Woods, 2002). A curriculum innovation causes a substantial change in the practice domain of experienced teachers, and requires that teachers change their teaching practice of the conventional curriculum, so they need to perform in atypical situations when teaching the new curriculum (Dunphy, & Williamson, 2004). When the change in domain asks more than the daily adaptations in practice different processes occur. Questions came up such as: Does teachers' expertise develop during practice? Or does it require courses outside school hours? Does it develop continuously or only when the domain of practice changes (Henze, van Driel and Verloop, 2009)? And how about the development of different types of teachers, and different categories of teacher's knowledge and expertise?

In this research project, it was found that the process of teachers' development in teaching new content occurs differently from development in using pedagogical approaches, and performing new teacher's roles. When teaching a unit, teachers focus on teaching strategies and assessment, and on the learning processes of their students, and less on learning goals and objectives concerning the (new) content, as was also found by Henze, van Driel and Verloop (2008). Consequently, they do not necessarily also develop understanding of the new content. As Henze et al. (2008) suggest, it was assumed that professional development activities, aimed at teachers reflecting on teaching experiences and sharing their pedagogical ideas and explicating their expertise, could be the main key to effective professional development of experienced science teachers. However, there are many ways and many activities that could be planned to support teachers' reflection and sharing of expertise. This research project contributed to investigate how to organise teachers' sharing and development..

This continues into the third reflective question about how to support teachers in curriculum innovations, by organizing professional development activities when the domain is changing so substantially, especially when the pedagogical approaches and content both change. Review studies have been conducted to retrieve strategies for the effective professional development of teachers (Avalos, 2011; Penuel, Fishman, Yamaguchi and Gallagher, 2007; Van Veen, Zwart, Meirink and Verloop, 2010), and specifically in collaborative settings (Brouwer, Brekelmans, Nieuwenhuis and Simons, 2012; Stoll, Bolam, McMahon, Wallace and Thomas, 2006; Vescio, Ross and Adams, 2008). There seems to be a certain agreement on general strategies — for example, collaboration, sharing experiences, reflection, and activities close to teachers' classroom practice — as effective strategies for enhancing teacher learning and development. The difficulty is to apply these strategies to specific situations, to support teachers to develop in a certain direction. More specifically, when the curriculum innovation involves new content, specific strategies need to be implemented to stimulate teachers to change their practice, and support them in teaching new content.

Many factors play a role during the learning process, and every learner can have a different style. Although, nowadays, trends in supporting and describing learning processes and strategies for students and teachers are shown in literature, as self-regulated learning, ownership of one's own learning process and professional development, collaborative knowledge creation and development, and so forth. It is hard to prove the causal effects of professional development activities on the development of teachers or students. As an extension of the results of this study, it is stated that in all cases senior members or participants in the specific domain of practice need to provide the learners with an organization of activities in which they can develop. Examples of such organization include: a framework for professional development, as used in this thesis; agendas for scheduled meetings; pre-described sequences of activities in units; and providing an overview about activities, processes and goals at the start of a lesson.

This organization of activities means that a social culture is created or cultivated in which it is 'normal' to share, reflect and learn. Then the novice teachers, students, employees socialize in this culture, and professional development activities become routine or just 'part of the job'. Consequently, most energy is available to learn and develop. In class, the organization is set by the teacher to facilitate the learning of the students. However, in the professional development programmes, in which teachers develop expertise in a collaborative setting, it is the coach that provides the organization of activities and the professional or social culture in terms of group dynamics and activities, by means of the agendas of the meetings and guidance of discussions. In the learning process of Ph.D. students, the supervisors need to organize activities for guidance and feedback, and in research institutes, the board and staff need to organize settings of collaboration in which the participants can learn, and expertise is developed.

This research project adds strategies to create such an organized activities for teachers to develop expertise in a collaborative setting. However, more importantly, this research project was a first initiative for organizing a national professional development network of teacher groups (Bulte and Seller, 2011). The network forms a social culture in which teachers socialize, learn collaboratively and develop expertise in and beyond the school organization. The curriculum innovation made it possible to create this network, because it provided a motive to learn among teachers, and a motive to facilitate building the network among policymakers, government and educational supporting associations and institutes. However, the continuation of the network is threatened when the new curriculum is implemented, because this direct motive for learning and facilitation becomes different. For continuous development of the curriculum, it is necessary to continue this network as a social culture, to sustain the continuous professional development of teachers. This is only possible when intrinsic motivation, like participation in the network helps teachers' to improve their practice and student learning, and extrinsic motivation as financial support of teachers are fulfilled. In addition the network need to be coordinated.

Reflection on the implementation of context-based chemistry education

This section describes the reflection on the experiences during this research project, about the implementation of context-based chemistry education. Although discussing the implementation of context-based chemistry education was not the focus of this research project, it is useful to reflect upon these experiences during the studies. The topics to discuss involve the process of scaling up the curriculum innovation, the conceptualization of macro-'meso'-micro thinking, teachers' feelings of scepticism towards the new curriculum, and using context settings and conceptual schemes to teach chemistry concepts.

In a first step in scaling-up the implementation of this innovation, about forty teachers were involved in teaching context-based chemistry units. Before this step, only small-scale initiatives were conducted to develop the theoretical backgrounds of the new curriculum, and to design units accordingly. In this research project, it was assumed that when teachers were involved in teaching context-based chemistry units, they would gain insight into the theoretical background of the context-based curriculum, and be able to contribute to the theoretical and practical knowledge base of the new curriculum.

Teachers taught the context-based units in class, shared their experiences, and discussed their problems during instruction at monthly meetings, together with coaches, researchers and designers. These meetings were important to create a basis and support among teachers, to implement the context-based curriculum. Based on the study described in Chapter 3, however, it was noticed that the discussions during the meetings involved mostly practical issues, so development of shared understanding about theoretical backgrounds of the new curriculum was limited. The understanding of new aspects of the context-based curriculum that were shared among coaches and designers, were not made explicit to the teachers. In addition, by teaching the units, teachers did not necessarily develop expertise in all new aspects of the unit. It was difficult for teachers to understand the theoretical background of the new aspects in context-based chemistry education, and so they experienced problems when instructing the units to their students.

One of the problems that teachers experienced was understanding the new content of macro-'meso'-micro thinking in structure-property relations. When teaching the conventional curriculum, teachers taught macro-micro thinking implicitly to the students. When participating in the monthly meetings, they learned about the new content of macro-'meso'-micro thinking in structure-property relation, in a presentation about the conceptual scheme of Meijer et al. (2009; see also Chapter 1, Figure 1). Later, in the following meetings, it was noticed that this presentation was not sufficient for them to fully understand and teach the new content of the units to their students. In addition, during the first empirical study (Chapter 2), five of these teachers were interviewed. Since teachers experienced problems in teaching the units, they expressed a lot of scepticism about context-based chemistry education.

When conducting the first case study, it was found that the coach and the researcher were not able to explain the new content of macro-'meso'-micro thinking to the teachers. One of the problems was that the new content of macro-'meso'-micro thinking, as represented in the conceptual scheme of Meijer et al. (2009), was not conceptualized sufficiently to apply in different contexts in chemistry, and other disciplines such as food technology, biochemistry and nanotechnology. In addition, a deeper understanding of the content of macro-'meso'-micro thinking was necessary in relation to the 'implicit' teaching of macro-micro thinking in the conventional curriculum to explain to teachers the new content of macro-'meso'-micro thinking in the collaborative setting. This resulted in the representations presented in Chapter 3 (Figures 3 and 4).

Looking back, it can be concluded that the impact of the curriculum innovation, especially of the new content, on teachers' practice was underestimated. It takes more than just a presentation to introduce new content to teachers, so they can develop understanding of what and how to teach. Changing the content of a curriculum means that the basis of teachers' practice disappears. This change causes teachers feelings of stress and insecurity, which hinders development of domain-specific expertise. The impact of this change was not expected at the start of this research project.

During the process of implementing the context-based chemistry education, teachers expressed scepticism towards this change in their practice. The scepticism that teachers expressed concerned mostly that teaching the unit in class takes too much time, with regard to the regular schedules of the school year. A few reasons can be given for why teachers were concerned about this. Firstly, teachers know in their routine practice, how much time it takes to teach specific activities and subjects to their students. When teaching units they did not know, they instructed the activities exactly as they were prescribed. In addition, they needed to experience how much time it takes for students to carry out these activities. Teaching the unit took a lot of time, and so teachers were concerned that, in this way, they could not teach all the concepts of the conventional programme.

Secondly, when teachers recognized subjects in the unit from the conventional curriculum, they taught the subject as they would do in their routine practice. This was not intended and not necessary for teaching the unit successfully. Consequently, the conventional curriculum and the new curriculum were mixed up, leading to an experienced overload, and both intended student effects were not fully achieved. When teachers experienced this the first time they taught a context-based chemistry unit, they sometimes became insecure and experienced feelings of stress.

The intention of the context-based chemistry curriculum is that students learn new chemistry concepts in a meaningful way within a context setting. Then students learn concepts in relation to each other in a mental map or conceptual scheme (Gilbert, 2006; Gilbert, Bulte and Pilot, 2011). Some teachers indeed experienced this in their classes. However, many teachers experienced the setting of the context as an additional aspect when teaching the concepts of the unit. Teachers expressed this by sharing that using context-settings and teaching units takes too much time in their schedule, when going on the expense of teaching the concepts. Those teachers found that using context-settings for teaching all concepts of the conventional curriculum is very time-consuming.

It is too early to judge and value the curriculum innovation. However, based on the experiences in this research project, context-based education, or aspects of it, shows potential for students to learn chemistry in a meaningful way. The curriculum needs further development, and there is more to learn by teachers, designers and researchers about how to design and teach context-based chemistry education.

Reflection on the limitations

What is the domain of practice in which the results and conclusions of this research project hold? In which situations are these conclusions valid? Every situation, every group of teachers and every curriculum innovation is different. The findings of this research project, based on two case studies of two groups of teachers in this specific and complex curriculum innovation, could not be generalized for all groups of teachers, curriculum innovations and professional development programmes. The strategies, framework, activities and functions are guidelines that might hold in variable situations. However, every situation needs a newly designed programme to support teachers' development in the specific domain, since teachers themselves are owners of the programme, and influence the activities and the direction in which development occurs.

The programme in this research project is an example, a proof of concept, of how such a programme could be planned. The strategies found in this research project need to be implemented and studied in a broader field, to investigate the usefulness and effects on teacher development. The programmes in this thesis were planned, based on literature, prior experiences and expertise of the coach, as well as on a lot of intuition and gut feelings. After the analysis of the data, six strategies were found that resulted, in these case studies, in the intended development of domain-specific expertise. The research needs to be continued to prove the value of these strategies in a scientific and professional sense, by implementing these strategies in a broader field, and in other situations and domains.

The input of designers and teacher educators is crucial in realising the value of the strategies found in this research project. These professionals design and implement professional development activities based on their expertise, experience, intuition and the specific situation. They are very important in judging the practical value of these strategies, by using them in their development programmes and educational designs. In the next section, implications and recommendations for researchers, designers and teacher educators are provided.

Implications and recommendations

When conducting this research project, the findings did lead to explicit and implicit understanding of teacher learning, programme design, strategy implementation, and curriculum innovations. Based on these understandings, recommendations and implications are provided. The following recommendations could be useful for the purpose of designers, teacher educators and coaches of professional development programmes.

To support teachers in a curriculum innovation that requires the simultaneous development of expertise in setting a context, performing a new role and teaching new content, the framework of professional development (represented in Chapter 1, Figure 2, and inspired by Stolk et al., 2012) did not provide sufficient support for teachers. An additional phase is necessary to provide teachers with adequate problem analysis to make sense of teaching the new content. This problem analysis is a prerequisite for developing domain-specific expertise in teaching the context-based chemistry units.

In addition, activities in the framework need to be organized in a quick sequence and iteration of preparation, instruction and reflection on teaching the new content. The interaction with students during instruction is essential for teachers to make sense and develop when teaching the innovative units. During the meetings, the activities need to provide teachers with the opportunity to share expertise in a safe environment, without criticizing each other, and to use this expertise in developing new strategies to teach the new aspects of the curriculum innovation.

When organizing and designing a collaborative setting in a professional development programme, the collaborative setting needs to consist of a senior teacher in the specific domain, teachers with some experience, and teachers without experience in teaching in this domain, and a less experienced or junior teacher. The senior teacher and junior teacher could create the 'double purpose' of the group that involves professional development and advising in the curriculum innovation, to stimulate sharing and create a constructive learning environment. The group dynamics, including the composition in the group and social interactions among teachers, influence the discussions and the development of domain-specific expertise. In the discussions, expertise and experiences of all new aspects need to be shared. In addition, there needs to be a balance between similarities and differences of the new and conventional curriculum.

Implementing a curriculum innovation is always accompanied by emotion, scepticism, hesitation, feelings of stress, and a lack of self-efficacy that hinders teachers' development (Carlyle and Woods, 2002). The coach can use the contributions of the experienced teacher in the group to garner support, and create a common ground and an open learning environment among teachers. The coach should be able to guide the discussions towards the intended direction of the new aspects in the curriculum. This stimulates teachers to share and use the contributions of colleagues, and think collaboratively of new strategies for teaching their students.

For researchers, further research is necessary to understand how to develop professional development programmes, to support teachers in curriculum innovations in general, and specifically, to find and investigate strategies in supporting teachers in teaching context-based education within a broader field. The hierarchy and power relations among teachers in a collaborative setting could be used in favour of teachers' intended development, by influencing the roles of the group members. The composition of teacher groups will always be heterogeneous. Therefore, the experience, background, school situation and initial expertise of teachers must be taken into account. Understanding the influence of the hierarchy and power relations that emerge is relevant, because that could help to direct the social interactions towards the new aspects of curriculum innovation, and thus teachers' development. Patterns in group dynamics and the influence of factors on teachers' development could be different for various cultures. An interesting subject for research would be why and how factors, such as social interaction, non-verbal communication, hierarchy and status, influence teachers' development in non-Western cultures.

In addition, further research is needed to evaluate the applicability of the framework of professional development programmes across other domains (e.g. biology, physics, history, languages), across other kinds of innovations (e.g. inquiry-based, competence-based education), and other educational levels (e.g. universities, primary schools). Further research could provide insight into how to balance the bottom-up approach of creating an atmosphere, which respects teachers' professional identity and ownership of their teaching, with a top-down approach, stimulating teachers to experiment in their classrooms, which is required to implement a curriculum innovation.

During this research project a lot was learned about the new curriculum, how to implement the new curriculum, and how to support teachers in teaching the new curriculum. The implementation of the context-based chemistry curriculum still requires a lot of effort and time. First steps have been taken, and a lot expertise has been developed by teachers, designers and researchers. Maybe this curriculum will be developed further and will be taught generally in all schools. If so, this can only be achieved by the teachers that participated in the initiatives, projects and communities described. If not, then some aspects from the context-based curriculum will still remain in the practice of the teachers involved, and will spread within the teacher population in the future. Without doubt, there are ambitious teachers, developers, researchers or others, that are already thinking of new ways to teach chemistry. These ideas will be the seeds of a new curriculum that might be implemented decades from now. For those who will be implementing curriculum innovations in the future, in which content and pedagogical approaches are both subject to change in teachers' practice, the strategies developed during this research project might be helpful to design professional development programmes.

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Summary

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Summary

This project builds on research projects about designing teaching-learning processes in structure-property relations in context-based chemistry education and designing a framework for teachers' professional development in curriculum innovations. The focus of this research project was to increase the understanding about learning processes of experienced teachers in collaborative settings to foster the implementation of the curriculum innovation of context-based chemistry education. To design a professional development programme to support teachers in this curriculum innovation, more understanding is necessary about strategies in the three design issues: 1. composing the collaborative setting, 2. planning activities within the programme and 3. determining and describing the development of the intended domain-specific expertise. The central research question of this research project is:

What strategies, implemented in a professional development programme, support teachers in developing domain-specific expertise in teaching context-based chemistry education?

To answer the central research question, this research project involves four empirical studies, that were related to the design issues. The first study was an explorative study to determine the new domain-specific expertise that teachers need to develop to teach context-based chemistry units. The following research question was the focus of this study:

What new domain-specific expertise do experienced chemistry teachers need to acquire in order to teach an innovative context-based unit about macro-micro thinking, using meso-levels in structure-property relations?

This study resulted in the description of the domain-specific expertise in terms of seven abilities that teachers need when teaching a context-based chemistry unit. For the second study these abilities were categorized in terms of (i) setting the context in class of project teams that are assigned to solve a problem in product development, (ii) performing the new teacher's role of senior member of the project teams and (iii) teaching the new content of macro-micro thinking in structure-property relations.

The second study focused on the development of the domain-specific expertise when teachers participate in a professional development programme. A case study was conducted, in which teachers guided by a coach taught a context-based chemistry unit in a collaborative setting. The case study provided an answer to the following research question:

What domain-specific expertise do teachers develop when they teach a context-based chemistry unit about macro–micro thinking in structure–property relations in a collaborative setting?

The results of this study showed that teachers developed new domain-specific expertise, when they prepared the unit collaboratively to instruct in their own school situation. However, they did hardly expand this newly developed expertise during instruction and reflection. The preparation phase within the professional development programme did not provide teachers with an adequate problem analysis on teaching the new content of macro-micro thinking in structure-property relations. This hindered them in expanding their expertise during the instruction and reflection phase. Based on these results, the focus of this research project was directed towards the group dynamics in the collaborative setting and planning of the preparation phase in the professional development programme.

The third study was conducted to explain teachers' (lack of) development of domain-specific expertise in a collaborative setting as described in the second study, from the perspective of group dynamics. This study provided an answer to the following research question:

What patterns in the group dynamics of collaborating teachers can be identified that influence teachers' development of the domain-specific expertise that is required for teaching a context-based unit?

Three patterns in group dynamics were identified that influenced the teachers' development regarding teachers' engagement, the roles of the group members and coordination of the coach. Pattern I '*Double group purpose*' and Pattern II '*Leadership of the coach towards sharing*', influenced the development positively. The lack of teachers' development in teaching the new content, was mostly explained by Pattern III: '*Hierarchy among the teachers*' based on experience in teaching context-based units. The hierarchy and roles among the group members were of great influence on the social interaction and the focus of the discussions and so on teachers' development of domain-specific expertise.

Based on the results described in the second empirical study, the fourth study focused on planning a sequence of activities to improve teachers' sense-making in teaching context-based chemistry units during the professional development programme. To develop domain-specific expertise, teachers need to accommodate their frame of teaching the conventional curriculum towards teaching the new curriculum. This study focused especially on providing teachers with an adequate problem analysis on teaching the new content of macro-micro thinking in structure-property relations. In a second case study, an additional phase and functions to achieve accordingly were added to the framework of professional development as implemented in the first case study. In this empirical study, the following research question was answered:

To what extent does the sense-making process during the professional development programme, based on the adapted framework, result in teachers' accommodation of the specific context-setting in class, the performance of the new teacher's role and, especially, teaching of the new content in context-based chemistry education?

The results showed that the professional development programme did lead to teachers' accommodation of setting the context in class, performing the new teacher's role and teaching the new content. The additional phase of problem analysis did lead to the teachers' toleration and accommodation of macro-micro thinking in structure-property relations.

From the empirical studies described, strategies could be retrieved to support teachers in developing domain-specific expertise in a collaborative setting, to teach a context-based chemistry unit. Three patterns in group dynamics were found that could be used as strategies (See below, I–III) in the professional development programme. In addition, from the results of the implementation of the adapted framework and additional phase of problem analysis in the professional development programme, three other strategies (IV–VI) can be delineated to support teachers in developing domain-specific expertise in teaching the new content of macro-micro thinking in structure-property relations. The six strategies are presented below:

I. <u>Double two-way purpose:</u> To engage teachers in discussions within the collaborative setting in order to develop domain-specific expertise in teaching context-based chemistry units, designers need to create a strategy of a 'double two-way purpose' for the group to participate: 1. They are facilitated to prepare themselves, with intensive guidance on the upcoming curriculum innovation; 2. They are assigned to advise the curriculum developers about the implementation of the curriculum in regular schools. The casting between the coach, as most experienced teacher, and the researcher, as least experienced teacher, maintains this 'double purpose'. This stimulates teachers' sharing of experiences and expertise during the discussions in the meetings, and so enhances their development of domain-specific expertise.

II. Leadership towards sharing: To create a respectful learner atmosphere, in which teachers are stimulated to develop new domain-specific expertise collaboratively in teaching the context-based unit, the coach needs to coordinate and direct the discussions towards sharing teachers' experiences in teaching the unit in their own classes. Then, teachers are approached as professionals and experts in their own school situation. By following up the instruction to let teachers share experiences by an instruction to use the experiences in group performances, teachers are prevented from criticizing each other's practice.

III. Hierarchy: To guide and direct discussions in the collaborative setting, it is useful that the coach makes the contributions of the more experienced teachers productive. However, the contributions to the discussions of the more experienced teachers are considered as more important than those of other teachers. Then, in the group, a hierarchy develops among the teachers, based on their prior experience in teaching context-based units. Consequently, the focus of the discussions is directed by the input of the more experienced teachers, and as such it influences the development of domain-specific expertise.

IV. Phase of problem analysis: To support teachers in teaching the new content, teachers need to conduct an adequate problem analysis on teaching the new content before they prepare to instruct the context-based chemistry unit. An adequate phase of problem analysis means that all functions described in the framework are fulfilled in relation to the new content.

V. Iteration of preparation, instruction and reflection: To achieve the functions to support teachers' problem analysis in teaching the new content, a sequence of activities needs to be planned regarding preparation, instruction and reflection on a lesson about the new content. The sequence of activities should provide teachers with an opportunity to get introduced to the frame of reference for the new content, and to become aware of their personal frame of reference on teaching the (new) content in the conventional curriculum. In this respect, a balance in focus needs to be created towards the differences and similarities between aspects in the conventional and the new curriculum. It is crucial to stimulate teachers to accommodate their personal frame of reference within the frame of reference for teaching the new content in their interaction with students.

VI. Hands-on activity: To stimulate teachers' development and sense-making towards teaching the new content of the new curriculum, the phase of problem analysis should involve a hands-on activity that teachers could use directly in class. As a result, teachers experience how they could teach the new content to their own students. This leads to teachers' toleration of teaching the new content as a first step towards accommodating their personal frame of reference towards teaching context-based chemistry education. In addition, linking student-learning effects to teachers' own learning goals is an important step in teachers' sense-making about the new content.

Reflections are discussed on the decisions and knowledge claim of this research project, on the implementation of context-based chemistry education during this research project, and on the limitations of the studies. The reflections on the decisions and knowledge claim are described according to three main reflective questions, about teacher's expertise and it's components and labels, about how this teachers' expertise develops in a changing domain, and how to support teachers in curriculum innovations when the pedagogical approaches and content both change. In the reflections on the implementation of context-based chemistry education, topics are discussed about the process of up scaling the curriculum innovation, the conceptualisation of macro-'meso'-micro thinking, teachers' feelings of scepticism towards the new curriculum, and using context-settings and conceptual schemes to teach chemistry concepts. In addition, reflections on the limitations of the studies are discussed.

Recommendations for teacher educators and designers, as well as researchers are provided. When designing a professional development programme, it is recommended to plan a phase of problem analysis on the new content, to plan activities in a quick sequence of preparation, instruction and reflection including the interaction with students, and to create a safe atmosphere for teachers to discuss and share expertise about teaching strategies and student results. The group needs to consist of teachers with various levels of experience. The coach should be able to guide the discussions towards all new aspects in the curriculum.

Further research is necessary to understand how to develop professional development programmes to support teachers in curriculum innovations in a broader field. In addition, the applicability of the adapted framework for professional development needs to be evaluated across other domains. Further research could give insight in how to balance between the bottom up approach of creating an atmosphere which respects teachers professional identity and ownership about their teaching, and the top down approach of stimulating teachers to experiment in their classrooms. An optimal balance is important to implement a curriculum innovation.

Samenvatting

Dit proefschrift bouwt voort op onderzoeksprojecten over het ontwerpen van onderwijs-leerprocessen over structuur-eigenschappen relaties in context-gebaseerd chemie onderwijs en het ontwerpen van een kader voor de professionele ontwikkeling van leraren in curriculum innovaties. De focus van dit onderzoeksproject is gericht op het verwerven van meer kennis over leerprocessen van ervaren docenten in groepsverbanden met als doel de implementatie van de curriculuminnovatie van context-gebaseerd chemie onderwijs te bevorderen. Om een professionaliseringsprogramma te ontwerpen om docenten te ondersteunen in deze curriculuminnovatie, is meer inzicht nodig binnen de drie ontwerpvraagstukken, te weten: 1. het samenstellen van de groep; 2. de planning van de activiteiten binnen het programma; 3. het bepalen en beschrijven van de ontwikkeling van de beoogde domeinspecifieke expertise. De centrale onderzoeksvraag van dit onderzoek is:

Welke strategieën ondersteunen docenten in een professionaliseringsprogramma in het ontwikkelen van domeinspecifieke expertise in het doceren van context-gebaseerd chemie onderwijs?

Met betrekking tot de ontwerpvraagstukken zijn voor het beantwoorden van de centrale onderzoeksvraag binnen dit onderzoekstraject vier empirische studies uitgevoerd.

De eerste studie was een verkennende studie om te bepalen welke nieuwe domeinspecifieke expertise docenten nodig hebben om context-gebaseerde chemiemodules te doceren. De volgende onderzoeksvraag staat centraal:

Welke nieuwe domeinspecifieke expertise moeten ervaren scheikundedocenten ontwikkelen om een innovatieve context-gebaseerde module te doceren over macro -micro denken, daarbij gebruikmakend van meso-niveaus in structuur-eigenschappen relaties?

Deze studie heeft geresulteerd in de beschrijving van de domeinspecifieke expertise in termen van zeven bekwaamheden, welke docenten nodig bleken te hebben om een context-gebaseerde chemiemodule te onderwijzen. Voor de tweede studie zijn deze bekwaamheden gecategoriseerd in termen van (i) de context-setting in de klas van projectteams, die een probleem moeten oplossen in productontwikkeling, (ii) het uitvoeren van de nieuwe rol van de docent als senior lid van de projectteams en (iii) het onderwijzen van de nieuwe vakinhoud van macro-micro denken in structuur-eigenschap relaties.

De tweede studie richtte zich op de ontwikkeling van domeinspecifieke expertise van docenten die deelnamen aan een professionaliseringsprogramma. Daarvoor is een case study uitgevoerd, waarin docenten in groepsverband, onder begeleiding van een coach, een context-gebaseerde chemiemodule onderwezen. De case study was gericht op de volgende onderzoeksvraag:

Welke domeinspecifieke expertise ontwikkelen docenten wanneer ze in groepsverband een context-gebaseerde chemiemodule doceren over macro-micro denken in structuur-eigenschap relaties?

De resultaten van deze studie toonde aan dat docenten, wanneer ze de module gezamenlijk voorbereidden om te doceren in hun eigen schoolsituatie, nieuwe domeinspecifieke expertise ontwikkelden. Deze nieuw ontwikkelde expertise hebben ze echter nauwelijks uitgebreid tijdens de instructie- en reflectiefase. De voorbereidingsfase in het professionaliseringsprogramma faciliteerde de docenten niet genoeg in het maken van een adequate probleemanalyse van het doceren van de nieuwe vakinhoud over het macro-micro denken in structuur-eigenschap relaties. Hierdoor werden ze tijdens de instructiefase belemmerd in het uitbreiden van hun expertise. Op basis van deze resultaten werd de focus van het onderzoek gericht op de groepsdynamiek en de planning van de voorbereidingsfase in het professionaliseringsprogramma.

De derde studie werd uitgevoerd om de (of het gebrek aan) ontwikkeling van domeinspecifieke expertise door docenten in het groepsverband, zoals beschreven in de tweede studie, te verklaren vanuit het perspectief van groepsdynamiek. Dit onderzoek richtte zich op de volgende onderzoeksvraag:

Welke patronen in de groepsdynamiek van samenwerkende docenten kunnen worden geïdentificeerd die van invloed zijn op de ontwikkeling van domeinspecifieke expertise om een context-gebaseerde module te doceren?

Drie patronen zijn geïdentificeerd in de groepsdynamiek, die van invloed waren op de ontwikkeling van domeinspecifieke expertise met betrekking tot de betrokkenheid van docenten, de rollen van de groepsleden en de coördinatie van de coach. Patroon I '*Dubbel groepsdoel*' en Patroon II '*Leiderschap van de coach in de richting van delen en uitwisselen*', hadden een positieve invloed op de ontwikkeling. Het gebrek aan docentontwikkeling in het onderwijzen van de nieuwe vakinhoud, werd vooral verklaard door Patroon III: '*Hiërarchie van de docenten op basis van ervaring in het doceren van context-gebaseerde modules*'. De hiërarchie in en de rollen van de leden van de groep waren van grote invloed op de sociale interactie en de focus van de discussies en als zodanig op de ontwikkeling van domeinspecifieke expertise van docenten.

Op basis van de resultaten beschreven in het tweede onderzoek, concentreerde de vierde studie zich op het plannen van een activiteitenreeks om de betekenisgeving van docenten aan het doceren van context-gebaseerde chemie modules, gedurende het professionaliseringsprogramma, te verbeteren. Om domeinspecifieke expertise te ontwikkelen, moeten docenten hun eigen referentiekader met betrekking tot het doceren van conventionele chemiecurriculum accommoderen richting het doceren van het nieuwe curriculum. Dit onderzoek richtte zich vooral op het bieden van een adequate probleemanalyse in het doceren van de nieuwe vakinhoud van de macro-micro denken in structuur-eigenschap relaties.

In een tweede case study, werden een extra fase en de te bereiken functies toegevoegd aan het kader voor professionele ontwikkeling van docenten, die vervolgens in de tweede studie uitgevoerd werd. In deze studie stond de volgende onderzoeksvraag centraal:

In hoeverre resulteert het proces van betekenisgeving van docenten in het professionaliseringsprogramma, gebaseerd op het aangepaste kader, in het accommoderen van docenten van de specifieke context-setting in de klas, het uitvoeren van de nieuwe docentrol en in het bijzonder het onderwijzen van de nieuwe vakinhoud in context-gebaseerd chemieonderwijs?

De resultaten toonden aan dat het professionaliseringsprogramma ertoe heeft geleid dat docenten de context-setting in de klas, het uitvoeren van de nieuwe docentrol en het doceren van de nieuwe vakinhoud accommodeerden. De extra fase van probleemanalyse heeft ertoe geleid dat docenten het macro-micro denken in structuur-eigenschap relaties tolereerden en accommodeerden.

De beschreven empirische studies leverden zes strategieën op om docenten in groepsverband te ondersteunen in het ontwikkelen van domeinspecifieke expertise om een context-gebaseerde chemiemodule te doceren. De drie gevonden patronen in groepsdynamiek kunnen worden gebruikt als strategieën in een professionaliseringsprogramma (I-III). Daarnaast heeft het aangepaste kader met de extra fase van probleemanalyse in het professionaliseringsprogramma, ook drie strategieën opgeleverd om docenten te ondersteunen bij de ontwikkeling van domeinspecifieke expertise in het doceren van de nieuwe vakinhoud van macro-micro denken in structuur -eigenschap relaties (IV-VI). We lichten deze zes strategieën in detail toe:

I. Dubbel groepsdoel: Om leraren actief te laten deelnemen aan discussies binnen het samenwerkingsverband om domeinspecifieke expertise te ontwikkelen in het geven van context-gebaseerde chemie modules, moeten ontwerpers een strategie van een 'dubbel groepsdoel' creëren in de deelname aan de groep: 1. Ze worden gefaciliteerd om, met intensieve begeleiding, zich voor te bereiden op de komende curriculuminnovatie, 2. Ze worden gevraagd advies te geven aan de curriculumontwikkelaars over de implementatie van het curriculum in het reguliere onderwijs. De rolverdeling tussen de coach, als de meest ervaren docent, en de onderzoeker, als minst ervaren docent, onderhoudt en stimuleert dit 'dubbel groepsdoel' tijdens de besprekingen in de bijeenkomsten, stimuleert het delen van ervaringen en expertise door docenten tijdens de besprekingen in de bijeenkomsten, en bevordert zo het hun ontwikkeling van domeinspecifieke expertise.

II. Leiderschap ter stimulering van het delen van ervaringen: Om een respectvol leerklimaat te creëren, waarin docenten worden gestimuleerd om samen nieuwe domeinspecifieke expertise te ontwikkelen in het doceren van context -gebaseerde modules, moet de coach de besprekingen coördineren en discussies zodanig leiden dat docenten ervaringen delen over het doceren van de modules in hun eigen klassen. Docenten worden zo benaderd als professionals en deskundigen in hun eigen schoolsituatie. Door het delen van ervaringen te vervolgen met een instructie om de ervaringen te gebruiken in groepsactiviteiten, wordt voorkomen dat docenten elkaars praktijk bekritiseren.

III. Hiërarchie: Om besprekingen in de groep te begeleiden en te sturen, is het voor de coach nuttig om de bijdragen van de meer ervaren docenten productief te maken. De bijdragen van de meer ervaren docenten aan de besprekingen kunnen dan echter beschouwd worden als meer belangrijk dan die van andere docenten. Er ontstaat dan in de groep een hiërarchie onder de docenten, op basis van hun eerdere ervaring in het doceren van context-gebaseerde modules. Daardoor worden de besprekingen gestuurd door de bijdrage van de meer ervaren docenten, en als zodanig beïnvloedt dit de ontwikkeling van domeinspecifieke expertise.

IV. Fase van probleemanalyse: Om docenten te ondersteunen in het doceren van de nieuwe vakinhoud, moeten docenten een adequate probleemanalyse in het doceren van de nieuwe vakinhoud uitvoeren, voordat ze de context-gebaseerde scheikunde module voorbereiden om uit te voeren in de klas. Een adequate fase van probleemanalyse houdt in dat alle functies die in het kader zijn beschreven worden vervuld met betrekking tot de nieuwe inhoud.

V. Snelle iteratie van voorbereiding, uitvoering en reflectie: Om de functies te vervullen en de probleemanalyse van docenten te ondersteunen in het doceren van de nieuwe vakinhoud, dient een activiteitenreeks te worden gepland waarin de voorbereiding van, uitvoering van en reflectie op een les over de nieuwe vakinhoud aan de orde kwam. In deze activiteitenreeks moeten de docenten de gelegenheid krijgen om kennis te maken met het referentiekader voor de nieuwe vakinhoud, en zich bewust te worden van hun persoonlijke referentiekader voor het doceren van de (nieuwe) vakinhoud in het conventionele curriculum. Daarbij dient een evenwicht te worden gecreëerd tussen het focussen op de verschillen en op de overeenkomsten tussen aspecten in het conventionele en het nieuwe curriculum. Het is cruciaal om docenten in de interactie met leerlingen te stimuleren om hun persoonlijke referentiekader aan te passen in de richting van het referentiekader voor het doceren van de nieuwe vakinhoud.

VI. Hands-on activiteit: Om de ontwikkeling en betekenisgeving van docenten te stimuleren in het doceren van de nieuwe vakinhoud van het nieuwe curriculum, moet de fase van probleemanalyse een hands-on activiteit bevatten die docenten direct kunnen gebruiken in de klas. Zo ervaren docenten hoe zij de nieuwe vakinhoud kunnen doceren aan eigen leerlingen. Dit leidt ertoe dat docenten de nieuwe vakinhoud tolereren, als een eerste stap naar het accommoderen van hun persoonlijke referentiekader in de richting van het doceren van context-gebaseerd scheikundeonderwijs. Bovendien, is het koppelen van leeropbrengsten aan de eigen leerdoelen van docenten een belangrijke stap in de betekenisgeving van docenten aan de nieuwe vakinhoud.

In dit proefschrift worden ook enkele reflecties besproken over de beslissingen en opbrengst van dit onderzoeksproject, over de implementatie van context-gebaseerd chemieonderwijs tijdens dit onderzoek en over de beperkingen van de studies. De reflecties op de beslissingen en opbrengsten zijn gericht op drie belangrijke reflectieve vragen: over wat expertise van docenten is en uit welke componenten die bestaat en de gebruikte labels, over hoe docenten deze expertise ontwikkelen in een veranderend domein, en hoe docenten ondersteund kunnen worden in curriculuminnovaties als zowel de didactiek als de vakinhoud onderhevig zijn aan verandering. In de reflecties over de implementatie van context-gebaseerd chemieonderwijs worden onderwerpen besproken als het opschalingproces van de curriculuminnovatie, de conceptualisering van macro-'meso'-micro denken, de sceptische gevoelens van docenten tegenover het nieuwe curriculum, en het gebruik van context-settingen en conceptuele schema’s om concepten in de chemie te doceren. Beschouwingen worden vervolgens besproken over de beperkingen van deze studies .

Voor lerarenopleiders en ontwerpers, maar ook voor onderzoekers worden enkele aanbevelingen gegeven. Bij het ontwerpen van een professionaliseringsprogramma is het raadzaam om een fase van probleemanalyse te plannen met betrekking tot de nieuwe vakinhoud. Ook het plannen van een snelle opeenvolging van voorbereiding, uitvoering en reflectie, interactie met studenten, en het creëren van een veilige sfeer voor docenten om expertise te delen over het onderwijsstrategieën en leerlingresultaten zijn essentieel. De groep moet uit docenten bestaan met verschillende mate van ervaring. De coach moet in staat zijn de discussies te begeleiden in de richting van alle nieuwe aspecten in het curriculum.

Er is vervolgonderzoek nodig om te begrijpen hoe professionaliseringsprogramma's moeten worden ontworpen ter ondersteuning van docenten in curriculum innovaties in het algemeen. Daarnaast moet de toepasbaarheid van het aangepaste kader van professionele ontwikkeling verder worden geëvalueerd binnen andere domeinen. Verder onderzoek kan inzicht geven in hoe een evenwicht bewerkstelligd kan worden tussen de bottom-up benadering waarin een sfeer wordt gecreëerd van respect voor de professionele identiteit en eigenaarschap van docenten over hun onderwijs, en de top-down benadering waarin docenten worden gestimuleerd om te experimenteren in hun klaslokalen. Een optimaal evenwicht is belangrijk voor het succesvol implementeren van een curriculuminnovatie.

Dankwoord

De strijd is gestreden, het is af. Ik wil alle mensen bedanken die een bijdrage hebben geleverd aan het proces en het product. Een paar in het bijzonder:

Allereerst de docenten en coach, die hebben mee gedaan in dit onderzoek: zonder jullie expertise, inzet en creativiteit was het zeker niet gelukt. Wat hebben we samen veel geleerd!

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De Woudschoten Commissie 2010: het organiseren van de Chemieconferentie samen met hen was het hoogtepunt van de afgelopen jaren.

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Curriculum Vitae

Ria Dolfing werd op 9 oktober 1980 geboren in Emmen. In 1999 behaalde zij het VWO diploma aan de CSG Dingstede te Meppel en startte de studie Zoötechniek aan de Wageningen Universiteit. Deze studie ronde ze in 2004 af in de specialisatie Veehouderij, met specifieke aandacht voor adaptatie fysiologie.

Begin 2005 volgde ze de snuffelvakken tot het leraarschap aan de Wageningen Universiteit en werkte ze bij VWO-campus. In september 2005 startte ze de postdoctorale lerarenopleiding Biologie aan de Radboud Universiteit te Nijmegen en werkte ze als LIO-docent Biologie aan de RSG Pantarijn te Wageningen. Schooljaar 2006/2007 vervolgde ze haar loopbaan als docent Mens en Natuur en Natuur/Scheikunde aan de CSG Baudartius College in Zutphen. Ook had ze in dat jaar een kortstondige betrekking aan de Hogeschool Arnhem Nijmegen bij de tweedegraads lerarenopleiding Biologie. In september 2007 startte ze haar promotieonderzoek, wat resulteerde in dit proefschrift.

Tijdens haar promotietraject heeft ze van Januari 2011 tot Juli 2012 als junior onderzoeker gewerkt bij de vakgroep Educatie en Competentiestudies van de Wageningen Universiteit. Sinds augustus 2012 werkt ze als vakdidactisch medewerker bij de Faculteit Wiskunde en Natuurwetenschappen aan de Rijksuniversiteit Groningen.

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Notes

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