Exploring a Framework for Professional Development in Curriculum Innovation: Empowering Teachers for Designing Context-Based Chemistry Education

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

Keywords Professional development · Curriculum innovation · Empowering teachers · Context-based chemistry education

Introduction

Designing professional development for science teachers during educational reform is a complex endeavour. Increasingly, design of professional development efforts is guided by frameworks for professional development. These frameworks provide tools for design and

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evaluation of professional development programmes, like different strategies for professional development or a focus on changes in science teachers' knowledge, beliefs and attitudes, changes in teacher practice, or improvement of student results (Bell and Gilbert 1996; Loucks-Horsley et al. 2003; Fishman et al. 2003).

Over the years, several professional development programmes have been designed and evaluated according to such frameworks (e.g. Parke and Coble 1997; Luft 2001; George and Lubben 2002; Jeanpierre et al. 2005). In most cases, the intended effects of these programmes were not or only partly accomplished. We have shown elsewhere (Stolk et al. 2009a), that these studies focus on the effects of their programmes and that little attention is given to the process of professional development, leading to these unsatisfactory results. Furthermore, it is unclear how these frameworks for professional development are elaborated into programmes and how the programme's activities contribute to teacher professional development. According to Hewson (2007), insight into teacher professional development during a programme can provide valuable information about the programme's design. In this study, we aim to acquire insight into the contribution from programme's activities to teacher professional development and contribute to the knowledge base on how to design a professional development programme.

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

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

Teacher professional development generally focuses on acquiring knowledge and skills. However, change is accomplished when teachers feel sufficiently confident to apply their new knowledge and skills in practice. As such, professional development of teachers is increasingly conceptualised as teacher empowerment (Bell and Gilbert 1996; Carl 2009). In this study we used design research to investigate chemistry teacher professional

development during an in-service programme. The programme was based on a framework for professional development (Stolk et al. 2009b). In this paper, we describe the design and evaluation of a professional development programme in which chemistry teachers carried out an educative context-based unit (Davis and Krajcik 2005), and, based on their teaching experiences, designed an outline of a new context-based unit. In the following section, we will briefly elaborate our framework.

A Framework for Professional Development

To acquire insight into the contribution of the programme activities to teacher professional development, we developed a framework. In this framework, a learning theory, which provided a description of a professional development process, was synthesised with strategies and specific goals for professional development (see for a more detailed description of the framework and its underlying assumptions, Stolk et al. 2009b).

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

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

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

During the motivation and orientation phase of the teaching strand, teachers create a preliminary orienting basis for teaching the context-based unit by becoming acquainted with the context-based unit and its underlying general model. During the application phase,

Fig. 1 Framework for professional development

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

experiences. After the designing strand, teachers' expanded orienting basis for designing consists of their ability and confidence to design an outline of a new context-based unit, and of their further understanding of the general context-based model.

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

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

Orienting Chart: the Context-Based Model and Unit

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

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

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

Fig. 2 General model of a context-based unit

provide students with a context-related justification in retrospect for studying chemistry concepts. The study of chemistry concepts is carried out simultaneously with an orientation on a context-based inquiry project.

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

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

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

Research Question and Research Strategy

The aims of this study were to investigate how to elaborate the framework into a professional development programme, and to acquire insight into the contribution of the programme activities to the process of professional development. A professional

development programme was designed and evaluated. Our research was guided by the following general research question: *To what extent does the elaboration of the framework for professional development empower chemistry teachers for context-based designing?*

To answer this question, we have used developmental or design research as a research strategy (Lijnse 1995; Cobb et al. 2003; Bulte et al. 2006). This strategy constitutes exploring the usefulness and consequences of theoretical ideas by working them out in a professional development process. The professional development process is then optimised in several research cycles, focused on testing, reflecting on and adjusting the designed programme and framework. Testing the designed professional development process takes place in a small-scale case study with a group of teachers as the unit of analysis. The design presented here is informed by theoretical evidence from previous literature studies (Stolk et al. 2009a, b). This study reports about the first, explorative, research cycle with the design.

The design is accompanied by a set of expectations on how the programme should function. These expectations describe the (learning) outcomes of each activity, and the actions that teachers are expected to perform. These expectations can be considered as hypotheses, as predictions of the professional development process that is expected to take place. As such, it enables the researchers to precisely observe where the actual professional development trajectory deviates from what was expected. Discrepancies between the expectations and the implemented programme will be used for improving the programme and, pending on the nature of the discrepancies, for improving the underlying framework.

To be able to determine whether the elaboration of the framework empowers chemistry teachers for context-based designing, we first describe the activities of the programme and the accompanying expectations. Next, we discuss the evaluation of the design: the methods used and the results obtained.

Design of the Programme

The programme is designed starting with the framework (see Fig. 1). The phases, goals and strategies are elaborated into specific activities. For each of the activities accompanying expectations are presented. A summary of the programme, including phases and activities is given in Table 1. For more details on the programme's design, see Stolk et al. (2009c).

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

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

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

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

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

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

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

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

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

Activity T3: Reflection on teaching

After teaching the educative context-based unit in their classrooms, the teachers were asked to discuss their teaching experiences. Subsequently, they were asked to use these experiences for elaborating the context-based model. First, we expected that the teachers would report that their students were amazed by the properties of disposable diapers. Second, we expected that the teachers would feel confident (that is, they had experienced involvement in decision-making, autonomy and self-efficacy) to teach this context-based unit. Third, we expected that they also would know how to solve the 'need to know' problem. Finally, we expected that the teachers would use their experiences to elaborate the general context-based model, by discussing which teaching strategies are appropriate for

context-based teaching and designing. In this reflective activity, the teachers should expand their orienting basis for context-based teaching. The use of the teaching experiences for elaboration of the context-based model should also contribute to creating a preliminary orienting basis for context-based designing (see Fig. 1).

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

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

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

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

Activity D3: Reflection on designing

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

Method

The Programme in Action

Following the design of the programme, we divided the general research question (To what extent does the elaboration of the framework for professional development empower

chemistry teachers for context-based designing?) into ten evaluative sub-questions. Each question is related to an activity of the programme. The code before the question identifies the corresponding activity (see Table 2).

A group of six chemistry teachers, all from different secondary schools, participated voluntarily in the programme. Four teachers (Harry, John, Donald and Norman)¹ had more than 25 years of teaching experience each, two teachers (Rick and Louise) had a range of 5 to 10 years of teaching experience. All teachers had a master degree in chemistry. They all had previous experience in other professional development programmes, and were regular attendees of chemistry teacher conferences. These teachers were willing to use innovative ideas and they supported the context-based curriculum innovation.

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

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

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

Data Collection and Analysis

A qualitative methodology was used to identify whether the expectations regarding teachers' professional development processes were met. Data were collected at specific moments that were closely associated with the design of the programme (cf. Baxter and Lederman 1999). During the meetings, ample field notes were made, and products created by teachers were collected. Between scheduled meetings, several lessons in which the educative context-based unit was taught were observed. When a lesson could not be observed, the teachers filled in a questionnaire in which they evaluated their lesson. Before and after the programme, all teachers were interviewed about their opinions regarding context-based chemistry education and the programme. All audiotapes were transcribed verbatim. Fragments of the critical instances were independently selected by the first and second author to verify whether the professional development process had unfolded as expected. Additional data from teacher products, questionnaires and interviews were used for triangulation when necessary.

¹ All names used in this research study are pseudonyms.

Table 2 Overview of the programme activities and sub-questions

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

As part of answering the sub-questions, the numbers of teachers who fulfilled the expectations related to a particular sub-question was determined. Four categories to indicate the number of teachers were used: all (6 teachers), most (4–5), some (1–3) and none (of the teachers). In some cases, it was not possible to collect data from all teachers due to duties elsewhere or illness. Harry was absent during activity T3, and Rick and Norman were absent during activities D2 and D3 (see Table 1). To determine teacher confidence for teaching and designing a context-based unit (sub-questions T3.1 and D3.1, see Table 2), teacher statements were categorised in terms of their perception of their involvement in a

Table 3 Meetings and activities

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

^aTeaching of the unit took place in class, between the meetings 1 to 4

decision-making process, autonomy, and self-efficacy (Short and Rinehart 1992). Thus, for example, when teachers expressed ‘to feel confident’ for an active role in curriculum innovation, teachers have the perception that they are involved in the decision-making process. In other words, teachers perceive that they have control about certain choices in the curriculum innovation process (autonomy). It is their perception that they can be effective in building programmes for students and to influence the students’ learning (self-efficacy).

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

Findings

Before answering the main research question (in the [Conclusions](#) section), we first answer the evaluative sub-questions.

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

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

T1.2: To what extent do the teachers design new teaching strategies to solve the ‘need to know’ problem?

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

from activities T1.1 and T1.2 indicate that the teachers created a preliminary orienting basis for teaching a context-based unit.

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

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

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

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

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

To indicate teacher confidence, exemplary teacher statements and summaries of teacher statements are presented with their assigned category (involvement in decision-making, autonomy, and self-efficacy, see the ‘[Data Collection and Analysis](#)’ section).

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

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

All teachers indicated that they did not solve the ‘need to know’ problem in their classrooms. They reported to encounter difficulties in motivating students to study the chemistry concepts about the molecular structure of the super absorbent material. All teachers reported that for many of their students these chemistry concepts were too difficult to understand without extensive teacher support (self-efficacy). With respect to the inquiry projects, all teachers reported that the students were motivated to carry out these projects. They also reported that their students hardly had to apply chemistry concepts in these projects. They concluded that the connection between these concepts and the inquiry projects was not clear (self-efficacy). During the group discussion in meeting 3, all teachers proposed several changes to the unit (autonomy, decision-making, see also the next

section). During the post-programme interview, all teachers intended to teach the context-based unit next school year (decision-making). During activity T3, all teachers expressed self-efficacy, autonomy and showed involvement in decision-making, and as such, all teachers felt confident to teach a context-based unit.

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

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

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

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

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

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

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

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

All teachers outlined a context-based introduction to the textbook chapter on dipole molecules, polar substances and hydrogen bonds (Pieren et al. 2001). For example, John

and Donald began their outline with a question “Why do substances dissolve?” They started with several student experiments on washing and surface tension (e.g. washing hands with different liquids, and soap added to a beaker of water with a floating object) for evoking a ‘need to know’ for studying the chemistry concepts in the textbook chapter. Next, all teachers sequenced their chemistry concepts similar to the sequence of these concepts in the original textbook chapter. Finally, most teachers designed outlines of context-based inquiry projects. They took several different laboratory experiments from the textbook chapter, and labelled them as inquiry projects.

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

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

To indicate teacher confidence, exemplary teacher statements and summaries of teacher statements are presented with their assigned category (involvement in decision-making, autonomy, and self-efficacy, see the ‘[Data Collection and Analysis](#)’ section).

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

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

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

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

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

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

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

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

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

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

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

In answering question D3.1, all teachers expressed self-efficacy and most of them showed autonomy and involvement in decision-making. This indicates that most teachers felt confident to use a general model of a context-based unit for designing.

In answering question D3.2, based on the limited amount of data, design activity D2 did not provide teachers with further understanding of the context-based model.

Conclusions

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

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

During the design activities, however, the actual professional development process deviated from our expectations. First, the teaching strategies designed to solve the ‘need to know’ problem (activity T1.2) were rather superficial, and, after applying these strategies, it became clear to the teachers that these strategies did not solve the ‘need to know’ problem. Second, all teachers encountered difficulties in designing an outline of a new context-based unit (activity D2), like designing a context-based introduction and changing the sequence of chemistry concepts in a textbook chapter. During the design, none of the teachers applied

the elaborated context-based model. Third, all teachers created a preliminary orienting basis for teaching the educative context-based unit. All teachers applied their preliminary orienting basis, however, some of the teachers did not apply it completely. As such, all teachers expanded their orienting basis for teaching and created a preliminary orienting basis for designing a context-based unit. But, during design of an outline of a new context-based unit, the teachers did not apply their preliminary orienting basis. However, they did notice that their preliminary orienting basis for designing was not suitable for designing new context-based units, and needed to be expanded.

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

Discussion and Implications

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

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

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

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

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

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