ADVANCES IN LEARNING ENVIRONMENTS RESEARCH

Teachers Creating Context-Based Learning Environments in Science

R. Taconis, P. den Brok and
A. Pilot (Eds.)

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Volume 9

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Scope

The historical beginnings of the field of learning environments go back approximately 40 years. A milestone in the development of this field was the establishment in 1984 of the American Educational Research Association (AERA) Special Interest Group (SIG) on Learning Environments, which continues to thrive today as one of AERA's most international and successful SIGs. A second milestone in the learning environments field was the birth in 1998 of *Learning Environments Research: An International Journal* (LER), which fills an important and unique niche.

The next logical step in the evolution of the field of learning environments is the initiation of this book series, *Advances in Learning Environments Research*, to complement the work of the AERA SIG and LER. This book series provides a forum for the publication of book-length manuscripts that enable topics to be covered at a depth and breadth not permitted within the scope of either a conference paper or a journal article.

The *Advances in Learning Environments Research* series is intended to be broad, covering either authored books or edited volumes, and either original research reports or reviews of bodies of past research. A diversity of theoretical frameworks and research methods, including use of multimethods, is encouraged. In addition to school and university learning environments, the scope of this book series encompasses lifelong learning environments, information technology learning environments, and various out-of-school 'informal' learning environments (museums, environmental centres, etc.).

Teachers Creating Context-Based Learning Environments in Science

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INTRODUCTION BY THE SERIES EDITORS

This volume of new research builds on past research into psychosocial learning environments and extends it to 'context-based' learning situations that have developed in various countries in an attempt to renew science curriculum and create new learning environments to fulfil the diverse needs of students, educators and society. Through context-based learning, it is hoped to raise motivation and lead to better understanding of science while also helping students to see relations between science and their everyday lives. These new learning environments are student-centred, potentially giving students more active and self-regulated roles in their education. Also these context-based learning environments provide interesting opportunities for research into and the application of learning environments theory and methods.

The historical beginnings of the field of learning environments go back over 40 years. A milestone in the development of this field was the establishment in 1984 of the American Educational Research Association (AERA) Special Interest Group (SIG) on Learning Environments, which continues to thrive today as one of AERA's most international and successful SIGs. A second milestone in the learning environments field was the birth in 1998 of *Learning Environments Research: An International Journal* (LER), which fills an important and unique niche. The next logical step in the evolution of the field of learning environments was the initiation of this book series, *Advances in Learning Environments Research*, to complement the work of the AERA SIG and LER. This book series provides a forum for the publication of book-length manuscripts that enable topics to be covered at a depth and breadth not permitted within the scope of either a conference paper or a journal article.

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Barry J. Fraser
David B. Zandvliet

RUURD TACONIS, PERRY DEN BROK AND ALBERT PILOT

1. INTRODUCTION

Context-Based Learning Environments in Science

CONTEXT-BASED EDUCATION

Context-based learning environments are being developed in various countries to renew science education and create new vital learning environments to fulfil the diverse needs of students, society and science (Osborne & Dillon, 2008; see also Chapters 2 and 12). Fensham (2009) observes an increasing interest in context-based science education from a large number of recent publications (De Jong, 2015; Meijer, Bulte, & Pilot, 2013; Millar, 2007; Roehrig, Kruse, & Kern, 2007; Sevian & Bulte, 2015; Sevian & Talanquer, 2014; Sjöström & Talanquer, 2014; Tytler, 2007).

There are clues that context-based learning environments can raise motivation (Bennett, Lubben, & Hogarth, 2007) and attempts are being made to show it can lead to better understanding of science as well (Fensham, 2009). In addition, it helps students to see relations between the science and everyday lives (Bennett, 2003). It may also help in conveying a more genuine image of the Nature of Science and science in society to the students, which is not only accurate, but inviting as well (Schwartz, Lederman, & Crawford, 2004).

Context-based learning environments are student-centred rather than scientist-centred, giving students a more active and self-steering role. In relation to all this, context-based education can lead to more students choosing science in school and professional careers, and to an increase in science literacy (Ültay & Çalık, 2012). The latter is particularly important in western industrialized countries, where students consider science hard to master and of little value to their lives and careers (Osborne & Dillon, 2008).

The central feature of context-based learning environments is the use of realistic contexts as a starting point and anchor for learning science, thereby giving significance and meaning to the science-content. This requires that the context provides "a coherent structural meaning for something new that is set within a broader perspective" (Gilbert, 2006, p. 960). A context should be relevant and recognizable for students. Real-life or scientifically authentic situations and activities are used as contexts in classroom (Gilbert, 2006). With this come secondary features such as, more room for the students to make their own educational choices, emphasis on debate and collaboration and on the process of science as well as on the nature of science.

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Roots and History

The idea of using contexts which are real and meaningful to the learners, for embedding science teaching and learning probably has long – and partly hidden – historical roots. These sometimes draw on local movements and traditions. In the Netherlands, for example, the development of context-based education appears to be inspired by the work of Freudenthal in the late 1960's who strongly pleaded for connecting mathematic education to everyday realities. Similar ideas have been present in other countries, and from the 1970's onwards they started to be explored systematically in various countries. Various projects like CHEMCOM in USA, LORST in Canada, SATIS and Salters' Science and Chemistry in England and Wales, and PLON Physics in The Netherlands all involved real world contexts with applications of science and technology.

In the UK 'the Nuffield Science Teaching Project' put great emphasis on inquiry and students' participation, and later on moved towards 'Science for Public Understanding', a context-based method (Nuffield Curriculum Centre, 2014). Extensive experience with context-based education was also gathered in the 'Salters Advanced Chemistry' program (Campbell et al., 1994). Finally, in the UK 'Twenty-first century science' (Ratcliffe & Millar, 2009) was developed.

On the American continent, and in the UK in the 1980s as a response to the challenge of 'Science for All' (e.g., USA: National Science Foundation, 1983; Canada: Science Research Council of Canada, 1984, UK: The Royal Society, 1985) innovative projects were started. These became associated sharing the slogan 'Science/Technology/Society (STS)' (Solomon & Aikenhead, 1994). In the USA ChemCom (Sanger & Greenbowe, 1996) offers a curriculum that bears all characteristics typifying context-based curricula, even though it would be described as a STS-curriculum (Science Technology, Society) in American discourse.

According to Aikenhead (1994), "STS science is student-oriented rather than scientist-oriented. […] STS instruction aims to help students make sense out of their everyday experiences, and does so in ways that support students' natural tendency to integrate their personal understandings of their social, technological and natural environments. […] Good science-technology-society science education is relevant, challenging, realistic, and rigorous. STS science teaching aims to prepare future scientists/engineers and citizens alike to participate in a society increasingly shaped by research and development involving science and technology."

In the Netherlands, the PLON-project in particular elaborated on these ideas for physics education (Eijkelhof & Lijnse, 1988). PLON came up with exemplified ideas on the use of context in science education and their way context and science concepts could be connected and become mutually supportive. That is: science concepts get their meaning from the relationships they have with other concepts and their relationships with application and meaning across a variety of natural contexts (Lijnse et al., 1990; Kortland, 2007; Gilbert, Bulte, & Pilot, 2011). By now a nationwide innovation of science education has been implemented aiming at context-based education (Van Koten et al., 2002).

In Germany the projects ‘Chemie im Kontext’ (ChiK) (Nentwig et al., 2005) and ‘Physik im Kontext’ (PiKO) have been developed (Duit, Mikelskis-Seifert, & Wodzinski, 2005).

Developments towards context-based science education can be found in various other countries such as South Africa (Brand, Gerrans, McCarogher, & Pool, 1991), Israel (Hofstein & Kesner, 2006), Trinidad and Tobago (George & Lubben, 2002), Ireland (Ellis & Gabriel, 2010), the USA (Schwartz, 2006), Turkey (Köse & Figen, 2011; Ültay & Çalık, 2012) and Autralia (Whitelegg & Parry, 1999; Hart, 2002; King, 2007).

LEARNING ENVIRONMENT RESEARCH

The study of learning environments is a thriving field within educational research. It is rooted in the work of Kurt Lewin, Henry Murray, Herbert Walberg, and Rudolf Moos (Fraser, 1998). Lewin’s (1951) field theory stipulated the very core idea of learning environment research; human behaviour has two potent determinants: the environment and its interaction with an individual’s personal characteristics. To illustrate this, Lewin (1936) created the formula $B = f(P,E)$ which states that behaviour is a function of the person and the environment.

Since then, learning environments research has grown considerably and various approaches, studies and instruments have been developed, tested and validated in various settings and countries and with a particular attention to science education contexts (Fraser, 1998; Fisher & Khine, 2006). All this has “provided convincing evidence that the quality of the classroom environment in schools is a significant determinant of student learning” (Dorman, Fisher, & Waldrip, 2006). There is compelling evidence to suggest that the classroom environment has a strong effect on student outcomes (Wang, Haertel, & Walberg, 1993; Fisher & Khine, 2006; Fraser, 2007). This implies that only studying the achievement of individual students has a limited value, since learning occurs within and under the strong influence of the learning environment (Fraser, 2007).

Recognizing the key importance of the learning environment for students’ learning outcomes demands adequate methods to measure map or typify learning environments. For this, learning environment research typically combines various information sources and employs both qualitative and quantitative information. Most often, learning environment research makes use of the perceptions of those involved in the learning environment (teachers, students, parents, leadership figures) next to other data sources (observation, documents), and distinguishes between either perceptions of the actual learning environment and the preferred or desired learning environment (Fraser, 2007).

Learning environment research gives a voice to both students and teachers in showing what is most effective in the classroom. Students' views in particular are considered an invaluable resource for understanding learning environments (Fraser, 1998) complementing observations and teacher reports.

Over the years, a vast range of instruments has been constructed, tested and validated to measure learning environments. This started with "social climate scales" (e.g. Moos, 1979) and the "Learning Environment Inventory" developed for the Harvard Project Physics by Anderson and Walberg (1974). Later on Fraser (1998; 2007) and others created various other well-known instruments to map learning environments as perceived by students and teachers such as the WIHIC (What is Happening in this Classroom), CLES (Constructivist Learning Environments Survey), QTI (Questionnaire on Teacher Interaction), etc. (Fraser, 2007). Like the CLES, some of these are specifically designed for analysing science learning environments.

In a broad perspective, the learning environment not only includes the physical structure and setup of schools, classes or institutions, but also their psychosocial-dimension (see Fraser, 2007). Major dimensions of learning environments often comprise relationships (of people in the learning environment), system maintenance and change, and (personal) growth (Moos, 1979). A review by De Kock, Sleegers and Voeten (2004) suggests that major dimensions to distinguish between different types of learning environments are (1) learning goals, (2) the division of learner and teacher roles, and (3) the roles of the learners in relation to each other. Broadly speaking, learning goals can, according to them, be divided into cognitive, affective and metacognitive ones; divisions between teachers and students range from more teacher-centred to more student centred; and environments can be more focused on individual learning on the one hand, versus more on collaborative learning on the other.

Moreover, learning environments have antecedents (conditions, input) as well as consequences (learning outcomes of students and teachers) (see Fraser, 1998) Hence, the lesson materials, curriculum and the teacher with his/her expertise, knowledge and behaviour, can also be considered as part of the learning environment. In Chapter 13 we mainly refer for the concluding reflections to the classification of learning environments by De Kock, Sleegers and Voeten (2004).

CONTEXT-BASED LEARNING ENVIRONMENTS

Context-based education addresses some problems that appear to occur in science education worldwide (Lyons, 2006). School science curricula tend to be overloaded with isolated facts, mostly derived from a theoretical practice of science with little or no connection to the students' reality (Gilbert, 2006). Students often perceive a lack of relevance and great theoretical complexity in their science learning environment. Taconis and Kessels (2009, p. 1116) give an condensed overview based on finding of various authors: "Students tend to see school science as 'dull, authoritarian, abstract, theoretical, fact-oriented and fact-overloaded, with little room for fantasy, creativity, enjoyment, and curiosity', 'difficult and hard to understand' (Sjøberg, 2002, cited in Schreiner, 2006, p. 57), and unfeminine (Kessels et al., 2006)."

Contemporary learning environments struggle with a number of dilemmas (Roelofs, Visser, & Terwel, 2003):

1. the construction of knowledge versus transmission of knowledge;
2. learning in complete task situations versus learning by means of split tasks;
3. focussing on personal meaning versus teacher-led meaning;
4. professional or scientific contexts versus formal school/education contexts;
5. cooperation and communication versus individual learning; and
6. developing learning climate (growth in expertise) versus momentary mastering.

School Science learning environments often focus on presenting 'a pile of fixed results' (Osborne, 2007) rather than on involving students in (adapted) authentic scientific *processes* (first dilemma). Even if the scientific process is addressed at all, it is often merely presented to students rather than experienced by them, and it is usually oversimplified (McComas, 1996; Kessels & Taconis, 2012). In addition, science teachers often appear to have limited knowledge about science-related careers (Osborne & Dillon, 2008).

In context-based learning environments, contexts are used as the basis for curriculum design and classroom teaching to solve these problems (Pilot & Bulte, 2006). Contexts bring coherence, connection, meaning and relevance by linking to ever-day-life realities and issues in economic life or society. This often leads to integral tasks stretching over various lessons instead of sets of separate tasks as is the case in more traditional lessons (second dilemma). Context-based learning environments also support students in engaging in scientific thinking and practice, thus improving their view on the Nature of Science and prelude possible career choices (Schwartz et al., 2004).

The central characteristic of context-based learning environments is that realistic context gives relevance and meaning to ideas and concepts covered in science lessons. Context-based learning environments support students in their attempts to understand their world by equipping them with the science knowledge and skills that support the gaining of deeper insight and understanding.

One line of thought is that a realistic and challenging context is taken as a starting point or anchor for learning science, thereby giving significance and meaning to the science-content (third dilemma). This concerns both practices and results. As Bennett, Lubben and Hogarth (2007, p. 348) put it: "context-based approaches are approaches adopted in science teaching where contexts and applications of science are used as the starting point for the development of scientific ideas. […] This contrasts with more traditional approaches that cover scientific ideas first, before looking at applications".

From a somewhat different perspective, it has been recognized that science concepts themselves are intertwined with the contexts in which they are created for and function in. So, concepts are inherently contextualized, in particular by their use. Hence, context is understood to involve a behavioural environment in which science concepts are used to address problems or issues perceived as relevant. Such a view puts emphasis on productive in-context student activities. Besides this, it recognises learning science-competent behaviour as a learning aim that is at least as important as acquiring science concepts. As King (2012) puts it: A context-based approach focuses on the application of science as a means of enhancing scientific understanding of students' real-worlds while developing students' capacities to function as responsible participants in their everyday lives (Aikenhead, 2006; Bennett, 2005). Such an instructional framework embodies a 'need-to-know.

In both perspectives, the energising interaction between realistic context and science learning, sometimes denoted as 'the need-to-know principle' (Pilot & Bulte, 2006; King, 2012), is the very core of context-based learning.

To be effective, contexts and context use must meet some requirements. Suitable contexts should provide "a coherent structural meaning for something new that is set within a broader perspective" (Gilbert, 2006, p. 960). The context and a particular problem or 'focal event' within it, set the agenda for further learning. As quoted by Gilbert, contexts should have:

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

To be effective, it is critically important that contexts are recognizable, understandable, relevant, valuable and inspiring to the students (fourth dilemma) and relate to the student's background knowledge (Gilbert et al., 2011). Day-to-day-life phenomena, authentic scientific or science-business situations and activities, or societal dilemma's and discussions are suitable examples (Gilbert, 2006). Apart from this, context-based learning environments should involve a manageable and productive 'behavioural environment' that allows or invites discussions for the constructions of understanding (Gilbert et al., 2011).

Context-based learning environments carry some accompanying characteristics. These features are critically relevant for their educational effectiveness (Peşman & Özdemir, 2012). Context-based learning environments are a coherent package in which the use of contexts is the pivoting characteristic.

First, in context-based education a clear constructivist perspective is taken. In line with current research in science education, learning is understood as a process in which learners construct their own meanings from their experiences, rather than acquiring knowledge by 'copying' it from other sources (Bennett, 2003; de Putter-Smits, Taconis, & Jochems, 2013). Context-based learning environments are constructivist learning environments. In most cases students are working together for the larger part of the time (fifth dilemma).

Within context-based education, learning i.e. the construction of knowledge is provoked as something you 'need-to-know' within the context and context related tasks (Pilot & Bulte, 2006). Context-based learning environments should promote asking questions and reward finding answers by building on students' pre-existing knowledge (Bennett & Holman, 2003; Bennett et al., 2007). Hence, concepts are learned within the context and derived from the context. On the other hand, transfer to other contexts often is organized in context-based learning environments by involving examples from other context and situations. All this may be best performed in learning environments encompassing 'collaborative learning', with ample opportunity for the exchange of ideas and sharing understanding.

Active learning is a second important and critical secondary feature of context-based learning environments (Gilbert, 2006; Parchmann et al., 2006). Emphasis on active learning is consistent with the constructivist view underlying context-based education (Gilbert, 2006). Active learning requires that students develop a sense of ownership of their learning and some room to act out their responsibility of their own learning. They should be allowed to make decisions on learning what, when and how within pre-set limits (de Putter-Smits et al., 2013). Context-based learning environments usually put emphasis on debate and collaboration and there may be particular attention for the process of science as well as on the nature of science. Some context-based learning environments involve students in a community of learners that mirror professional science communities as authentic as possible.

A sixth dilemma that context-based learning environments touch upon is that students have to be stimulated to take individual decisions on their own learning (e.g. focus on a particular aspects within the context) rather than focus on momentary mastering (Bulte et al., 2006). Due to this focus on students' individual learning and, at the same time, the need to employ inspiring and realistic contexts, teachers may have to improvise and redesign part of the learning environment from time to time (de Putter-Smits, Taconis, Jochems, & van Driel, 2012). As such, in context-based learning environments teachers also play a role as designers and implementers of material to the teaching practice (Duit et al., 2007; Parchmann et al., 2006; Vos, Taconis, Jochems, & Pilot, 2011).

Four Models

Gilbert (2006) gives four models based on the use made of contexts:

1. context as the direct application of concepts,
2. reciprocity between concepts and applications,
3. context provided by personal mental activity,
4. context as involving the social circumstances.

In model 1, contexts are used only for applying the previously learned content. The context and the concepts learned are relatively unrelated. In model 2, contexts and concepts are interrelated. That is: the concepts meaningfully apply to the contexts and add some insight to them and may help in finding particular answers relevant to the context. Within different contexts, a different set of concepts may be meaningful and concepts may have different meanings in different contexts. Model 2 helps students understanding the context and adding meaning and relevance to the concepts. However, the context does not offer students a rationale or motive for learning. Gilbert, Bulte and Pilot (2011, p. 824) state that in these models "the notion of 'context' is largely decorative: it is certainly not central to the learning that takes place."

In model 3 the context has the form of some 'realistic situation with a particular challenging problem that can (only) be solved when the targeted knowledge is mastered'. Hence, the situation/problem provokes and steers learning, but the behavioural environment is not implied by the context. In model 4, the social dimension of a context is fully recognised (Gilbert, Bulte, & Pilot; 2011, p. 825). The context additionally defines the behavioural environment, e.g. a particular role the learner should take on within a particular social setting. For example, being a scientific adviser who is asked to bring out a convincing report on a particular business of societal dilemma.

Context is central in the models 2 and 4, and in this book the authors tend to focus on context-based learning environments belonging to model 2 or 4.

Challenges

Realizing context-based learning environments in the practice of school-curricula involves various challenges.

First of all, aspects of the context-based approach as such may still need further development. One particular relevant issue is that of the relation between the subject knowledge acquired, and the context. Traditionally, this is considered to be a matter of *transfer* of (formalized) science knowledge. From sociocultural or competence oriented perspectives, however, the issue is defined differently. A vivid discussion exists on matters of de- and/or re-contextualizing of scientific knowledge constructed and the possibility or value of de-contextualized knowledge (van Oers, 1998; de Abreu, 2002, Gilbert, Bulte, & Pilot, 2011; King, 2012).

Another issue is that of *fair measurement of the learning outcomes* of context-based learning. Evaluative studies usually fail to demonstrate that context-based education produces superior learning outcomes. This may be partly due to the difficulty classical tests have in recognizing valuable yet contextualized and sometimes idiosyncratic learning outcomes of context-based education. Pilot and Bulte (2006, p. 1107) stress the need of appropriate testing. Testing should not overfocus on 'de-contextualized' knowledge and reward particular competencies that are particularly addressed in context-based education (e.g. “explaining phenomena scientifically”, as is the case in the latest PISA evaluations (Fensham, 2009; Sadler & Zeidler, 2009).

A third challenge concerns the *educational innovation as such*. Educational innovations never come easy. Changing from traditional science education to context-based science education fundamentally change learning environments, posing a challenge for learning environments research. Particular problems are the rigour of examination syllabi and regulations in some countries, the inertia of school-systems, convincing teachers holding other beliefs about good teaching or the benefits of context-based learning environments, and organizing the availability of materials, support and teacher professional development. Learning environments research holds a great potential in initiating and monitoring the progress of innovations, but relatively few studies have been reported that tie learning environments research methods and instruments to actual educational innovations (Fisher & Khine, 2006; Fraser, 2007). Learning environments research could critically contribute by describing the actual learning environments teachers manage to create, by analysing how and why teachers succeed or fail in doing so, and by monitoring the progress of the innovation. All of this would provide valuable information that could help individual teachers, could underpin decision making and could inspire ideas for further development.

Teachers and Context-Based Learning Environments

Both implementing context-based curricula in schools and creating context-based learning environments in classrooms critically depend on teachers. Teachers are a critical factor in creating the desired context-based learning environments (Yerrick, Parke, & Nugent, 1997; Mansour, 2009). Van Driel, Beijaard and Verloop (2001, p. 137) state that efforts to reform science education “have often been unsuccessful because they failed to take teachers’ existing knowledge, beliefs, and attitudes into account”. The general picture seems to be that curricular innovations reach teachers through a change in program/syllabus and teaching materials. In this, it seems a relatively rare event that teachers are being informed about the ideas behind the innovation, or get additional training (Vos, Taconis, Jochems, & Pilot, 2010). On the other hand, within some context-based innovation projects (e.g. PLON, ChiK), only an elite of teachers appears to be directly involved in creating context-based teaching materials.

Vos and colleagues (2010) studied how beginning and proficient teachers when confronted with context-based teaching materials, failed or succeeded in actually creating context-based learning environments. They argue that for experienced science teachers besides concrete and direct instruction in using the materials, teachers are also required to have knowledge of the rationale behind the material, should hold values on education that are congruent to those in the material, and should have the skills necessary to actually create a context-based learning environment while using the materials (see also Vos et al., 2011). De Putter-Smits and colleagues (2012) explored the competencies teachers need to actually successfully create context-based learning environments in their classroom. Like Nentwig, Christiansen and Steinhoff (2004), they suggest that teachers need competencies in testing in accordance with context-based teaching. This yields the provisional list of required teaching competencies:

- to understand the context at hand,
- to be able to handle contexts in educational practice adequately,
- to be willing and able to focus their lessons on more than just formal science knowledge,
- to be able to coach and (help) regulate the learning process of student that have a relative freedom on what, when and how to learn,
- to be able to flexible adapt the learning environment as to facilitate the various learning trajectories taken (redesign),
- to be able and willing to compose adequate tests for fair and complete assessment, and
- to be able and willing to advocate and demonstrate the context-based approach to their colleagues and within their schools.

The last competence is particularly relevant for successfully implementing context-based education at the level of the whole school.

Last but not least, teachers creating context-based learning environments should also be willing and able to comply with more general requirements for effective learning environments and constructivist learning environments, such as quick and adequate feedback, a good personal relationship with the students, and a learner-centered teaching approach (Cornelius-White, 2007; Duschl, 2008; Hattie, 2003).

ABOUT THIS BOOK

This book is part of the *Advances in Learning Environments Research* book series from Sense, and seeks to provide the reader with an overview of studies that explore context-based learning environments in science and particularly relate these to the competencies and learning of the teachers creating them in classroom. We aim to shed light on some issues in particular: what do context-based learning environments in science look like, what competencies do teachers need to successfully use them, how are teachers being supported in this? In this book we particularly look for the contribution that learning environments research can make in providing an answer to these questions.

In the book, we conceive learning environments in their broadest sense. Some contributions may concern the description or analysis of a context-based learning environment, while others may focus more on the antecedents or consequences than on the environment itself. Various contributions use ‘classical’ instruments known in learning environment research to map perceptions of students and teachers

(WIHIC, CLES, QTI etc.). These are sometimes combined with newly developed instruments and qualitative methods.

The book's audience comprises learning environments researchers, but teachers, teacher educators and school leaders as well. The book provides rich information for researchers in both general education as well as science education. Various organized groups may take interest in this volume in line with the focus in their activities.

The chapters describe studies from various science domains, countries and types of context-based learning environments, and are ordered in two sections:

I. Perceptions and characteristics of context-based learning environments, and
II. Teachers and creating context-based learning environments.

In section I, both students' perceptions and teachers' perceptions regarding context-based education are covered. In section II, teachers' approaches to creating context-based education as well as their competencies and the development of these competencies will be addressed. Where possible these will be linked to characteristics of the resulting context-based learning environment.

The first section of the book focuses on perceptions and characteristics of context-based learning environments and is comprised of Chapters 2 thru 5.

Chapter 2 '*Bringing science to life: research evidence*' deeply explores the nature of context-based approaches, following Gilbert's model 2 in particular. It also presents key findings of research on the cognitive and affective responses of students, and points to a number of issues concerning evaluating the effectiveness of context-based learning environments.

In Chapter 3, '*Place-based learning environments: environmental education in teacher education*', the context-based learning environment is not inside the school, but coincides to a large extent with the real environment. Hence, the very social setting of education is part of the context (Gilbert's model 4). Apart from introducing place-based learning environments and their construction, this chapter particularly discusses measurement issues.

Chapter 4 on '*Science kits*' explores a practical way to realize context-based learning environments in chemistry. The kits can actually be seen as a tool to convince reform-resistant teachers to take the chance and integrate contexts into their classrooms, with little demand on their skills and motivation.

Chapter 5 on '*Teaching and learning in context-based science classes*' elaborates a dialectical sociocultural approach, which clearly classifies as model 4 according to Gilbert. The description and analysis shows the critical relevance of students' agency and motivates active and creative involvement for reaching learning results that have meaning outside the educational context itself.

In the second section of the book, the teacher's role in creating context-based learning environments is directly addressed. It is comprised of Chapters 6 thru 12.

Chapter 6, '*Teachers in learning communities*', explores the role learning communities can play when teachers are taking up the challenge of creating context-based learning environments. After initially focussing on the defining characteristic of context-based learning environments – the use of contexts –, and staying close to their primary concerns such as practicability and the learning results, the teachers autonomously expanded their focus as they got more experienced in context-based teaching.

Chapter 7, '*Measuring context-based learning environments in Dutch science classrooms*' takes on the challenge of mapping context-based learning environments and relating its characteristics to teacher experience and student characteristics. Part of the study draws on the CLES and WIHIC questionnaires, which are frequently used in learning environments research. Teachers' experiences in creating context-based learning environments appear to lead to students' perceiving their learning environment as context-based, but interestingly teachers' own perception tend to deviate from those of their students. It appears that teachers strongly determine how context-based a learning environment is, but mainly via their choice of teaching material. The use of a standard book in combination with context-based materials seems to provide the best basis for creating a context-based learning environment, since too large emphasis on openness of the content and self-steering may lead to uneasy and unhappy students.

Chapter 8, '*Interaction between teachers and teaching materials*', further explores how teachers take up the challenge to create a context-based learning environment by context-based learning materials. Four factors are found that help (or hinder) teachers in creating context-based learning environments on the basis of these materials: a coherent design of the teaching materials, availability of concrete support and adequate context-based teaching skills with the teachers, competence in understanding the material's rationale by the teachers, and value congruence between the teacher's view and the context-based approach behind the materials. However, it also appears that materials that directly guide student-activities may lead to context-based learning environments, even without these four conditions being satisfied, since in such a case 'students have a major impact in shaping classroom practice'.

In Chapters 6, 7, and 8 the predominant model of context-based education seems to be Gilbert's model 2. However, in Chapter 9 '*Supporting teachers to transform their classes into a context-based learning environment',* the shared activity of doing a scientific inquiry forms the context of learning science (Gilbert's model 4). Another aspect of this chapter is the way the teachers are supported in building such a context-based learning environment: intensive individual coaching on the basis of teacher concerns and giving direct feedback to the teacher. It strongly focuses efforts of teachers on creating a classroom culture of inquiry shared classroom practice fostering the understanding of theoretical concepts. Changes took place in teachers' cognitions and attitudes, and in teaching practices, favourable to the creation of context-based lessons.

Chapter 10, '*Analysing middle school students' perceptions of their science classroom in relation to attitudes and motivation*', uses the Constructivist Learning environment Survey (CLES), the Test of Science Related Attitudes (TOSRA) and the Motivated Strategies for Learning Questionnaire (MSLQ) to evaluate the impact of context-based learning environments on students. It shows that context-based learning environments indeed are and should be designed and brought into classrooms as genuine constructivist environments.

In Chapter 11, '*A framework for empowering teachers for teaching and designing context-based chemistry education*', designing a new context-based teaching unit is employed as a vehicle for teacher empowerment. The chapter provides a framework that is helpful in understanding how teachers can be supported in creating context-based learning environments and distinguishes between two major components, namely teaching and designing. For each component steps are delineated that describe how professional development takes place and to what criteria it should adhere. It also provides starting conditions that are needed to embark on successful professional development for creating context-based learning environments. The training in designing context base teaching materials appears to have provided teachers with an understanding of the use of contexts in chemistry teaching, made them more confident in designing context-based education, and empowered them to create context-based chemistry learning environments.

Chapter 12, '*Context-based science education in senior secondary schools in the Netherlands*', presents and surveys teachers' views on context-based approaches as promoted in the Dutch national science education reform. Teachers perceive the programs as new because of the use of contexts or the use of contexts in a different way they have experience with. This differs over various school subjects. As far as physics teachers are concerned 'context-based education' seems to be predominantly interpreted as 'model 3', a set of particular comprehensive realistic problems to be solved without prescribing a 'behavioural environment'. As far as biology teachers are concerned, the model 4 interpretation appears to be relatively strong. Physics teachers do not always recognize the context-based reform as new. Some teachers, biology teachers in particular, recognize that the context-based approach promotes the internal coherence of the programs. All teachers appear to recognize that the new context-based science programs increase relevance and attractiveness for students. Context-based science programs appears to be viewed differently and enacted differently between teachers that were involved in pilot projects and teachers that were not. Pilot teachers placed concepts in contexts and stimulated students to also use such concepts in different contexts (re-contextualization). Only the pilot teachers thought the context-based curricula will make the programs less overloaded.

In a concluding chapter (Chapter 13), the main points in the various contributions are brought together and are linked to current trends and developments.

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SECTION I

PERCEPTIONS AND CHARACTERISTICS OF CONTEXT-BASED LEARNING ENVIRONMENTS

JUDITH BENNETT

2. BRINGING SCIENCE TO LIFE

Research Evidence

INTRODUCTION

This chapter addresses four important areas in the use and effects of context-based approaches in the teaching of science. The first part of the chapter considers the nature of context-based approaches. The second part of the chapter draws on a synthesis of a range of research studies to explore the impact of context-based approaches on student's cognitive and affective responses to science ideas. The third part of the chapter considers some of the issues raised by the review on research into the effects of context-based approaches. Finally, the chapter considers ways in which teachers might be supported and encouraged to make use of such approaches to enhance learning environments in school science.

Looking back over the last three decades, one of the most discernible trends in science curriculum development in a number of countries has been to use contexts and applications of science as a means of developing scientific understanding. This trend is apparent across the whole age spectrum from primary through to university level, but is most noticeable in materials developed for use in the secondary age range, for students between the ages of 11 and 18. Contexts are selected on the basis of their perceived relevance to students' immediate and future lives, and include social, economic, environmental, technological and industrial applications of science. Teaching science in this way has come to be known as using a context-based approach.

The widespread use of this approach raises a number of questions. What is the appeal of context-based approaches to teachers and others involved in decisions about the use of science curriculum materials? What impact do context-based approaches have on students understanding of science ideas? What impact do context-based approaches have on students' attitudes to science? What differences are there in the effects on girls and boys, or students of different ability? What impact does following a course that uses context-based approaches have on students' decisions about studying science subjects beyond the compulsory period?

WHAT ARE CONTEXT-BASED APPROACHES?

Gilbert (2006) identified four models for the design of context-based courses: (1) context as the direct application of concepts; (2) context as reciprocity between

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concepts and applications; (3) context as provided by personal mental activity; (4) context as the social circumstances. The work reviewed in this chapter largely fits into the second of these models, i.e. context as reciprocity between concepts and applications. Gilbert, Bulte and Pilot (2011) describe this model as providing:

> … a situation … selected (by the teacher or course designer) as a vehicle through which key concepts can be taught. The assumption is that there is a cyclical relation between concepts and context throughout the teaching, that is after the concepts are taught, their application in the context is presented, and then a new aspect of the context is focused upon as a prelude to the teaching of new concepts. (p. 823)

The fundamental principle of such context-based approaches is that contexts and applications of science should be used as the starting point for the development of scientific ideas. This contrasts with more conventional or traditional approaches that cover scientific ideas first, before looking at applications. Examples of such context-based approaches include studying medical diagnostic techniques to introduce ideas about electromagnetic radiation and atomic structure, looking at a range of fabrics to introduce ideas about materials and their properties, or looking at the structure of medicinal drugs to introduce ideas about organic chemistry.

Context-Based Approaches and Science-Technology-Society Approaches

Context-based approaches have much in common with Science-Technology-Society (STS) approaches, as is evident from the definition of STS approaches provided by Aikenhead (1994). He describes STS approaches as those that emphasise links between science, technology and society by means of emphasising one or more of the following: a technological artefact, process or expertise; the interactions between technology and society; a societal issue related to science or technology; social science content that sheds light on a societal issue related to science and technology; a philosophical, historical, or social issue within the scientific or technological community. The term ‘context-based’ is more common in Europe, whilst ‘STS’ is preferred in North America.

The Aims of Context-Based Approaches

A number of authors have articulated a range of aims for context-based/STS approaches (e.g. Aikenhead, 1994; Bennett, Lubben, & Hogarth, 2007; Castano, 2008; Gilbert, 2006; Gilbert et al., 2011; Parchmann et al., 2006; Yager & Weld, 1999). Whilst these may differ in the details, they share in common the notions that context-based approaches have affective, behavioural and cognitive aims, which encompass some or all of the following aspirations:

- to broaden the appeal of science by showing how it relates to people’s lives;
- to show the ways science is used in the world and in the work that scientists do;

- to engage and motivate students in their science lessons;
- to improve attitudes to school science and to science more widely;
- to develop effective understanding of science ideas;
- to increase the numbers studying science subjects beyond the compulsory period;
- to produce scientifically-literate citizens.

Affective Aspirations for Context-Based Approaches

Arguably, the most significant of the aspirations of context-based approaches lies in the area of students' affective responses to science – how they feel about the science they do. Certainly, widespread concern in a number of countries has resulted in a considerable amount of research time being devoted to students' attitudes to science and ways in which they might be addressed. In addition to 'in-country' studies, international studies, such as the Relevance of Science Education (ROSE) project (Schreiner & Sjøberg, 2004) and the 2006 Programme for International Student Assessment (PISA) (OECD, 2007) have gathered international data on students' attitudes to science and students' engagement in science. Typically, though not exclusively, the majority of the countries that have developed and or adopted context-based approaches are those where there is a concern over students' affective responses to science, and the hope is that the approaches will motivate students and make them feel more positive about science by helping them see the importance of what they are studying.

Behavioural Aspirations for Context-Based Approaches

Linked to affective aspirations for context-based approaches is the hope that increased interest on the part of students in science lessons will be translated into a desire to study science subjects beyond the period when they are compulsory. There is longstanding and widespread concern in a number of countries, particularly industrialised countries, over the uptake of science. This concern is also linked to projected shortfalls in the workforce of people with science and science-related qualifications, and one outcome of this has been detailed monitoring in a number of countries of post-compulsory uptake of science subjects (e.g. in Australia: Ainley, Kos and Nicholas, 2008; in Canada: Industry Canada, 2007; in the USA: National Science Foundation, 2010; in Europe: OECD, 2009; in the UK: Roberts, 2002; Sainsbury, 2007; The Royal Society, 2008).

Cognitive Aspirations for Context-Based Approaches

Context-based approaches have a number of cognitive aspirations for students' learning: they desire to develop sound understanding of science ideas, to broaden students' knowledge of how science relates to people's lives, and how it is used, and the work done by scientists. Such knowledge is essential for the development of scientifically-literate citizens: people who can make sense of some of the many ways that science impinges on their everyday life.

For many involved in the development of context-based materials, there is also the hope that, if students are more interested and motivated by the experiences they are having in their lessons, this increased engagement will result in improved learning of science ideas. However, the effective development of understanding of scientific ideas poses a particular challenge for context-based approaches because of the implications for the way that science ideas are introduced. If ideas are introduced as they arise in particular contexts – in other words, on a 'need to know' basis – then it is unlikely that any one concept area will be introduced and developed in full in one particular context, as might be the case in more conventional courses. At best, it could be argued, context-based approach provides opportunities for a 'drip-feed' approach, or a form of 'spiral curriculum', where ideas introduced in one context can be developed and re-enforced in other contexts, and this would lead to improved understanding. However, there is also the risk that students following context-based courses develop a poorer understanding of science as they are unable to link the ideas they encounter into a coherent picture.

THE IMPACT OF CONTEXT-BASED APPROACHES ON STUDENTS

The next section of this chapter focuses on the impact on students of context-based approaches. The evidence presented has been gathered and synthesised using the systematic review methods developed as part of the *Evidence, Policy and Practice Initiative* (*EPPI*), a UK Government-sponsored project whose aim is to synthesis and disseminate research findings in key areas of education.

The Origins and Aims of Systematic Reviews

Systematic reviews of research studies are a comparatively recent development in education, though they are well established in medical research. They have emerged from the international debate over the nature and purpose of educational research, and how it contributes to maximising the effectiveness of educational provision (e.g. Hargreaves, 1996; Hillage et al., 1998, in the UK; Shavelson & Towne, 2001, in the USA).

There are several reasons why systematic reviews are being seen as a key strand in educational research. Firstly, there is a growing interest in practical policy-related decision making being linked to evidence in a number of areas, not just in education. Systematic reviews of research literature are seen as having the potential to yield evidence on which policy makers can draw. Secondly, there is a drive towards forging closer links between research, policy and practice. In particular, drawing on research findings in classroom practice is seen as desirable, with teachers being encouraged to engage in what is variously described as 'evidence-based', 'evidence-informed' or 'evidence-enriched' practice.

It was for these reasons that, in 2000 the Government in the UK funded, via the Department for Education and Skills (DfES), the Evidence for Policy and Practice Initiative (EPPI)-Centre to focus on systematic reviews of research evidence in key areas of education. The Centre is based in the Social Science Research Unit at the Institute of Education in London and works in partnership with Review Groups located around the UK. The Review Group for Science is located in the Department of Education at the University of York.

Systematic Review Methods

The systemic review process, as developed by the EPPI-Centre, involves several stages: (a) identifying an area for review, and a specific review question within this; (b) searching for potentially relevant studies; (c) screening studies against agreed criteria to decide which should be included (criteria relate to, for example, aspects such as the age of students, the nature of the research design, and the reported outcomes); (d) coding the studies against specific criteria to build a systematic map of research in the area; (e) extracting the key information from the studies through an in-depth review; and (f) assessing the quality of the evidence generated. A key step in the process, the in-depth review, involves extracting information from studies in a systematic way. This information includes: the aims and rationale of the study being reported, the research questions; the design methods, the methods used for data collection and analysis, steps take to maximise the reliability and validity of methods of data collection and analysis, the results and conclusions, the quality of the reporting, and the strength of the evidence presented.

More detail of the review process, together with a critique of the approach, may be found in Bennett et al. (2005).

The Scope of the Review of the Effects of Context-Based Approaches

The review research question developed for the work discussed in this chapter was: *What evidence is there that teaching approaches that emphasise placing science in context and promote links between science, technology and society (STS) improve the understanding of science ideas and the attitudes to science of 11–18-year-old students?* The studies included in the review had their principal focus as an evaluation of the effects of context-based approaches on 11–18-year-old students' understanding of science ideas or attitudes to science as discrete independent variables. The studies were published in English and in the period 1980–2003. (The review was commissioned in 2003 and therefore could not include later studies.) Student age was restricted to 11–18 because the majority of context-based curriculum development projects have been aimed at this age range. The start date for the period of publication was dictated by the fact that the earliest examples of context-based materials date from the beginning of the 1980's.

OVERVIEW OF REVIEW FINDINGS

The searches yielded some 2500 studies, of which sixty-one met the inclusion criteria for the review. The chief characteristics of the work are summarised below.

Fifty of the sixty-one studies were carried out in the US, the UK, the Netherlands and Canada. Forty-one studies were undertaken with students in the 11–16 age range, and eighteen with students in the 17–20 age range. The emphasis on students in the 11–16 age range is likely to reflect the perception of this age group being very critical in terms of interest in science declining.

Just over half the studies (35) focused on interventions characterised as 'science'. Where there was a single-subject focus within this, thirteen related to chemistry, ten to physics and three to biology. It is likely that the focus on chemistry and physics in the individual science disciplines reflects the motives for developing context-based materials in the first instance, with chemistry and physics being seen as subjects with less appeal than biology.

Twenty-four of the sixty-one evaluation studies employed experimental research designs, i.e. data were gathered from a control group experiencing a conventional teaching programme, and an experimental group experiencing the context-based intervention. The remainder explored effects only on students experiencing the context-based materials. Interest in cognitive and affective aspects was roughly equal with, forty-one of the studies reported on aspects of understanding of science ideas and forty-four on attitudes to science. Of these, twenty-four reported on both aspects. Two other aspects that also emerged as featuring prominently in studies were the effects in relation to gender (17 studies) and low ability (7 studies). It was striking that the effects of gender and low ability are explored almost exclusively for the 11–16 age range, where science is mostly taken as a compulsory subject. Twenty-one studies also reported on development of skills. It was decided not to pursue this aspect in any detail in the review because the very wide range of interpretations of the word 'skills' would have raised questions over the validity of any synthesis of the evidence.

The most commonly used measure of effect in the experimental studies was, unsurprisingly, pencil-and-paper test results, used in almost two-thirds of the cases. The tests were either tests of understanding of science ideas, or some form of attitude inventory. In a substantial majority of cases, these tests were specifically developed for the evaluation being undertaken, and this points to one of the issues to do with the quality of the evidence, discussed later in the chapter. Questionnaires and interviews featured more prominently in non-experimental studies.

THE DETAILED REVIEW

As the review focus was on the impact of context-based approaches on understanding and attitudes, it was decided to limit the in-depth review to the studies that had employed an experimental design and, within this, to concentrate on the better quality studies. Although the systematic review process is clearly articulated, it is important to appreciate that its application to 'real' research studies is not straightforward, and making judgements about the quality of studies is not always easy, particularly when they involve complex interventions such as context-based approaches. Criteria were therefore developed against which studies could be judged. These related to the focus of the study (understanding and/or attitude, with these as explicit independent variables), research design, the reliability and validity of the data collection methods and tools (including the measures to assess understanding and/or attitude, the reliability and validity of data analysis, the sample size and the matching of control and experimental groups, the nature of the data collected (pre and post intervention, or post intervention), the range of outcome measures, and the extent to which the situation in which the data were collected was representative of normal classrooms. Application of these criteria resulted in seventeen of these twenty-four studies being judged to be of suitable quality to include in the in-depth review. The evidence presented below is therefore based on the findings of these seventeen studies.

Appendix 1 summarises the key features of each of the studies, including the context-based intervention on which the study focused, and the design of the evaluation.

Fifteen of the seventeen studies reported evaluations of interventions that took the form of whole courses with a duration of at least one-year, though, within this, five studies focused on a subset of the course as a whole in the evaluation, such a unit on equilibrium, or genetics. The remaining two studies gathered data on enrichment modules, i.e. shorter interventions that were not intended to be whole courses.

With the exception of the studies of three studies, where no details were provided, all the interventions received external funding for their development. In contrast to the funding for the development of the intervention, only five of the evaluation studies received any funding on the basis of information provided in the studies. A pattern of funding being much more strongly tied to the development of the intervention, rather than its evaluation, is very typical of context-based programmes. The funding pattern also often results in evaluations of interventions being carried out by the developers, an issue discussed later in this chapter.

WHAT IMPACT DO CONTEXT-BASED APPROACHES HAVE ON STUDENTS' UNDERSTANDING OF SCIENCE IDEAS?

The evidence on understanding of science ideas comes from the findings of twelve studies. Four of the studies indicated that context-based approaches resulted in a better understanding of science ideas than in conventional courses, while seven of the twelve studies indicated that context-based approaches develop a level of scientific understanding comparable to that of conventional courses. Only one study reported poorer understanding as the outcome. Full details of the findings may be found in Bennett et al. (2007).

Taken together, these findings do suggest that understanding is not adversely affected by following a context-based approach, and that, in some cases, it might be enhanced. Some of the studies reporting improvements attributed this to the 'drip feed' or spiral curriculum approach, though no specific evidence of this link was established (and it would be hard to gather such evidence).

How Large Were the Changes in Understanding?

If a change is noticed as a result of an education intervention, one question that can be asked is, how large is the change? In the last decade the literature on education evaluation has pointed to the use of measures of 'effect size' to quantify the difference in performance between groups, such as a control group and an experimental group receiving an intervention. Effect sizes tend to be described as 'small' if less than 0.2, and 'large' if greater than 0.4 (see, for example, Cohen, 1969). Typically, educational interventions tend to have small effect sizes.

None of the four studies that reported improved understanding, made references to effect sizes, but two presented their data in sufficient detail for effect sizes to be calculated. Both had effects that would be described as 'large' (see above), with one having a particularly large effect. In this latter case, the instrument used to test levels of understanding was developed by the same team who developed the materials, as part of an ongoing research and development programme on STS education, though there was no suggestion at all in the paper that this had inadvertently introduced any bias into the findings. However, it may be the case that the issue concerning style of assessment items mentioned earlier is also having an effect here.

WHAT IMPACT DO CONTEXT-BASED APPROACHES HAVE ON STUDENTS' ATTITUDES TO SCIENCE?

The evidence on attitudes to school science and to science comes from the findings of nine studies.

The most common approach to gathering data on attitude was the use of inventories involving agreement/disagreement scales (Likert-type questionnaires). In all but one of the cases where these were employed, the instruments were developed by the researchers specifically for the study.

Seven of the nine studies reported evidence that indicates context-based approaches improve attitudes to school science (or aspects of school science) and/or science more generally. Of these studies, three presented data that had been subjected to statistical analysis, and each indicated that the effects were statistically significant at the 0.05 level. In one case, there was sufficient data to calculate an effects size, and this was 0.67 – a large effect. (The evaluation tools used here had been designed by the developers of the intervention.) The remainder of the studies either employed simple descriptive statistics or gathered data for which statistical analysis was not appropriate.

One study reported evidence that indicates context-based approaches promote attitudes to school science comparable to those promoted by conventional courses, and one study reported evidence of a negative effect on attitudes to science.

Gender Effects

Gender effects were explored in five of the studies. This is unsurprising, given the longstanding concern over the differential involvement of boys and girls in the biological and physical sciences.

Three of the studies suggested that gender differences in attitudes are reduced through the use of a context-based approach. Two studies suggested that girls in classes using a context-based approach held more positive attitudes to science than girls in classes using a conventional approach. There was also evidence from one study to suggest girls following context-based courses were more positive than their peers following conventional courses to pursuing careers involving science, with results being significant at the 0.01 level. Taken together, these findings suggest that there is moderate evidence to indicate that context-based/STS approaches promote more positive attitudes to science in both girls and boys, and reduce the gender differences in attitudes.

Post-Compulsory Uptake of Science Subjects

Only three of the studies collected data relating to student's plans for studying science beyond the compulsory period, and students' career intentions. This is, perhaps, rather surprising, for two reasons. First, students' views in these areas are seen as important indicators of attitudes to science. Second, a desire to increase numbers in post-compulsory study with a view to pursuing careers in science-related jobs is one of the aims that underpins many of context-based courses. The evidence reported is mixed, with two studies reporting increases in numbers electing to study science subjects and one reporting no change. It is worth noting that one feature which distinguishes the studies reporting increased uptake from that reporting no change is that, in the latter case, the author was not the teacher of the students from whom the data were collected. This points to individual teacher effects exerting a strong influence on students.

Overall, the review findings on attitudes to school science and science appear to provide strong evidence that context-based approaches foster more positive attitudes to school science than conventional courses. There is more limited evidence to suggest context-based approaches foster more positive attitudes to science more generally than conventional courses, and mixed (and limited) evidence on the impact of context-based approaches on science subject choices in the post-compulsory period. Full details of the findings may be found in Bennett et al. (2007).

ISSUES IN RESEARCH INTO THE EFFECTS OF CONTEXT-BASED APPROACHES

Synthesising the evidence on the effects of teachers using context-based approaches raises a number of issues about research in the area, and the strength of the evidence base generated.

The Nature of the Resources

The information in the study reports included in the review focused on the evaluation data, and very few, if any, examples of the resources were included. It is clear from the study reports that the terms ‘context-based approaches’ (and ‘STS approaches’) can be interpreted quite broadly. Examination of the intervention resources which were available showed the use of contexts that were relevant to students’ lives and interests at present or in the future, related to technological developments and artefacts likely to be of interest to students, and were relevant to students’ possible future careers. At more advanced levels of study, there were also links to recent scientific research and innovations, to the work of scientists, and to industry. This diversity of contexts suggests that some caution is needed in interpreting the findings of this review, as it is difficult to imagine that all contexts have the same effects on all students. However, this caveat can be set against a background of the consistency of the evidence yielded by the studies taken as a whole.

Evaluating Designs

This chapter has focused on evaluations with experimental designs, and it is interesting to note that only twenty-four of the sixty-one studies identified adopted some form of experimental design. The political climate, at least in the UK, over the last decade has been one in which the education research community has been urged to make more use of experimental designs to generate solid evidence to inform policy decisions (see, for example, Hargreaves, 1996; Oakley, 2000; Torgerson & Torgerson, 2001).

However, there are practical constraints which may contribute to experimental designs being less feasible in educational contexts, particularly in relation to the evaluation of large-scale curriculum interventions. Decisions on participation in such interventions can rarely be made by researchers, and this means that it is very difficult to allocate students or classes randomly to groups that will or will not receive an intervention. Most often, the research design has to be built around existing class sets in schools. In the studies in this review, the sampling very often had an opportunistic dimension in that schools and classes using a new intervention were identified, and then other schools using more conventional course were identified to create a comparison group of roughly similar size. Practical constraints also frequently make it necessary to gather data from intact classes, and this raises issues to do with the construction of matched samples for control and experiential groups.

Who Collects the Data and Why?

Two of the features noted when summarising the studies for the review were the relationship of the study author(s) to the interventions being evaluated and the purposes for which the data were being collected. It was very noticeable that this information was often difficult to identify in the study reports and, in almost all cases, had to be drawn by inference. In the majority of cases, the researchers were either involved in the development of the intervention or users of the intervention. The authors of three of the studies collected their data for personal interest as part of their studies for a higher degree. Nine of the studies appeared to have been undertaken by people who also had a significant involvement in the development of the materials. The involvement of the developers in the evaluation does raise ethical issues about introducing possible bias into the evaluation findings, as it could be argued that developers have a vested interest in demonstrating their intervention has been successful. However, the studies included in this review did appear to take steps to minimise such bias.

Standardisation of Instruments

The studies employed a variety of instruments to gather data on both understanding and attitudes. In almost every case, new instruments were developed, though some drew on other instruments. This variety means it is difficult to make direct comparisons between studies or undertake meta-analysis of data. It is interesting to consider why research in the area has this characteristic. Certainly there would be some merit in a greater degree of consistency in the instruments used, which could, depending on the outcomes, strengthen claims made about the findings. However, the work is also characterised by its international dimensions, and, as international studies such as the PISA study have demonstrated (OECD, 2007), there are considerable challenges in developing instruments for use in a number of countries, where it is likely that there will be different educational frameworks and curricula. Such factors militate against the validity of using some form of cross-national instruments, though there would appear to be scope for more widespread use of standard diagnostic questions to assess understanding of topics.

Measuring Understanding

The measurement of understanding in relation to context-based and conventional approaches does raise a particular issue about the nature of the items used, which can be illustrated by the findings on of one of the studies undertaken in England. Here, students take an external examination at age 18+ (Advanced-level). Several examination options are available, including one assessing a context-based course. The overall standard of all these final examinations is regulated by an external body, which specifies content to be covered, which is common to all the examinations. However, at the time the study was undertaken, there was a considerable degree of latitude permitted in the choice of teaching approaches and the style of examination questions. This meant that students could follow a context-based course which was also assessed through context-led questions, rather than the more conventional examination questions. In addition to external examinations at age 18+, the Royal Society of Chemistry (a prestigious scientific body) has developed over some years a test bank of standard chemistry questions which it makes available to teachers to use if they so wish to assess their students' knowledge. The study reported that students taking a context-based chemistry course got lower scores on the Royal Society of Chemistry test than students taking a conventional course. However, when the same groups of students took their final examinations, the students following the context-based course did better than students taking the conventional course. One of the other studies reports a similar finding when different styles of assessment questions were used. The implication is that students on different types of courses are likely to perform better on assessment items that resemble the style of course they are following.

IMPLICATIONS FOR TEACHERS AND TEACHING

For some teachers, the appeal of a context-based approach is 'obvious'. It maps on to their pedagogic content knowledge in that it formalises what they already know from experience: if you want to engage a class of students, you have to capture their interest with something to which they can relate. Thus some teachers, when they hear about context-based approaches for the first time, identify with the underlying philosophy, and they can they can see it working in their lessons because it draws on what they already do, albeit in a more structured and explicit way. This match can be termed 'value congruence' (see also Chapter 8; Harland & Kinder, 1997). Such teachers will not be difficult to persuade to try context-based approaches in their teaching.

For other teachers, it may be that 'harder' evidence is needed, and the review findings reported in this chapter may persuade teachers that there is a sound evidence base pointing to a number of benefits of a context-based approach over a more conventional approach. In particular, the majority of students report that they enjoy their science lessons more, students understand the science they do at least as well as they would on conventional courses, and that some students feel more positively disposed towards science. Such evidence can be presented to teachers by those developing context-based resources.

However, whilst value congruence and research evidence may persuade some teachers to adopt context-based approaches, most will need additional help and support. Teaching science in context requires a departure from traditional teacher-driven learning to a style incorporating more learner-centred activity (Cho, 2002; Lubben, Bennett, Hogarth, & Robinson, 2004). Analysis of a range of resources developed to support context-based approaches (e.g. Salters suite of courses in the UK, the 'Chemie im Kontext' suite of programmes in Germany; see Chapter 6) shows that they typically employ a wider range of teaching strategies (e.g. small-group discussions, role-play, student presentations) than is normally associated with conventional science courses. As Parchmann and Luecken (2010) note, this can be challenging for teachers, as they are likely to feel less comfortable with such teaching strategies, particularly when they are encountered for the first time.

Thus, a particularly important aspect of context-based approaches is that resources are produced in a form that makes them easy for teachers to see what the approach means in practice, and provides concrete guidance on how the resources should be used. A characteristic of the most successful and enduring context-based programmes is that the task of translating principles into practice has been done for teachers through the development of student worksheets and other student resources. This provides teachers with the crucial support they need to give them the confidence to try out different activities in the classroom, and is also likely to contribute to the development of 'value congruence'. Incorporating non-threatening opportunities to practice the use of such materials into professional development courses is also likely to help teachers develop their confidence. Producing material in a form that is ready for use in the classroom also goes a considerable way to addressing a problem well-articulated by Black and Wiliam (1998) when considering the matter of what makes teachers change their approaches:

> Teachers will not take up attractive-sounding ideas, albeit based on extensive research, if these are presented as general principles which leave entirely to them the task of translating them into everyday practice – their classroom lives are too busy … for this to be possible … What they need is a variety of living examples of implementation, by teachers with whom they can identify, and from whom they can derive both the conviction and confidence that they can do better, and see concrete examples of what doing better means in practice. (p. 10)

CONCLUSIONS

This chapter has considered the nature of context-based approaches, and presented the findings of a research synthesis on their impact on students' cognitive and affective responses to science teaching. The synthesis suggest that studies of the effects of context-based approaches do yield a body of evidence to support claims that such approaches have a positive impact on students' attitudes to their science lessons, and that students learning of science concepts is comparable with that of more conventional approaches. The review does, however, point to a number of issues to do with evaluating the effectiveness of context-based approaches, relating both to interpretation of the term, research approaches adopted and instruments used to assess attitudes to science and understanding of science.

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(* = studies used in research synthesis)

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APPENDIX 1: OVERVIEW OF THE STUDIES IN THE REVIEW

	Study	*Country*	*Context-based intervention*	*Focus*
1	Banks 1997	England	Salters Advanced Chemistry, a two-year context-based course for students aged 17–18.	Understanding
2	Barber 2000	England	Salters Advanced Chemistry (see Study 1 for details)	Understanding Attitudes
3	Barker and Millar 1996	England	Salters Advanced Chemistry (see Study 1 for details)	Understanding
4	Ben-Zvi 1999	Israel	Science and Technology For All, a one-year STS course for non-science students.	Understanding Attitudes
5	Key 1998	England	Salters Advanced Chemistry (see Study 1 for details)	Attitudes
6	Lubben et al. 1997	Swaziland	Matsapha project materials taught to students aged 13–14.	Understanding
7	Ramsden 1997	England	Science: the Salters Approach, a two-year context-based science course for students aged 14–16.	Understanding
8	Rubba et al. 1991	USA	STS module taught to students aged 14–15.	Understanding
9	Smith and Bitner 1993	USA	ChemCom, a one-year STS course for high schools students (taught to groups aged between 12 and 17).	Understanding
10	Smith and Matthews 2000	Ireland	One-year STS course for students aged 14–15 (Transition Year).	Attitudes Gender
11	Tsai 2000	Taiwan	STS-Taiwan, a one-year STS course for students aged 16.	Understanding
12	Wierstra 1984	The Netherlands	PLON (Projekt Leerpakketontwikkeling Natuurkunde, Dutch Physics Curriculum Development Project) project, a five-year context-based physics course for students aged 12–17.	Understanding Attitudes Gender
13	Wierstra and Wubbels 1994	The Netherlands	PLON (see Study 12 for details)	Understanding Attitudes
14	Winther and Volk 1994	USA	ChemCom (see Study 9 for details)	Understanding
15	Yager and Weld 1999	USA	Scope, Sequence and Continuity (SS&C), a five-year context-based course for students aged 11–16.	Understanding Attitudes Gender Ability
16	Zoller et al. 1990	Canada	STS British Columbia, a one-year STS programme for 16–17-year-old students.	Attitudes Gender
17	Zoller et al. 1991	Canada	STS British Columbia (see Study 16 for details)	Attitudes

(Continued)

	Study	*Evaluation sample details*	*Summary of evaluation design*
1	Banks 1997	N = 95 students Control: 17 Experimental: 78 Age: 17–18 Schools: 6	One multi-part diagnostic question covering equilibrium. Data gathered pre and post intervention.
2	Barber 2000	N = 120 students (Attitudes) Control: 60 Experimental: 60 N = 35 students (Understanding) Control: 20 Experimental: 15 Age: 17–18 Schools: 1	Understanding: 14-item test based on test devised by Royal Society of Chemistry; also external examination grades and measures of 'value added'. Attitude: self-developed questionnaire (Likert scale and free-response items) plus interviews. Data gathered post-intervention.
3	Barker and Millar 1996	N = 140 students Age: 16–18 Control: 70 Experimental: 70 Schools: no details	Focus on one six-seven-week module, Energy and the Human Being. 22 diagnostic questions on elements, compounds and mixtures; chemical change; conservation of mass in closed and open systems; reacting masses; chemical bonding; thermodynamics; equilibria and rates of reaction. Data gathered at three points: start of course, after 7 months and after 15 months.
4	Ben-Zvi 1999	N = 232 students Control: 102 Experimental: 130 Age: 15 Schools: no details	22-item attitude inventory to explore attitudes to science and school science; Note: Study also used 15 semantic differential scales relating to 'image of science'. Data gathered post-intervention.
5	Key 1998	N = 1200 students Control: 300 x 3 Experimental: 300 Age: 17–18 Schools: no details	Three questionnaires probing impressions of industry and perceptions of relevance to study of chemistry. Note: Study involved comparing three conventional courses with context-based course, hence three control groups. Data gathered at three points: start-of-course, immediately after visit, and end-of-course.
6	Lubben et al. 1997	N = 288 students Control: 184 Experimental: 104 Age: 13–14 Schools: 6	Focus on unit on current electricity. 10 questions (standard examination items testing recall, understanding and application). Data gathered post-intervention.
7	Ramsden 1997	N = 168 students Control: 84 Experimental: 84 Age: 13–14 Schools: 8	Written questionnaire containing 8 diagnostic questions on mixtures and compounds, chemical change, conservation of mass. Data gathered post-intervention.

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	Study	*Evaluation sample details*	*Summary of evaluation design*
8	Rubba et al. 1991	N = 197 students Control: 100 Experimental: 97 Age: 15–16 Schools: 2	Focus on unit on genetics. Self-developed tests of achievement. Data gathered pre- and post-intervention and at one other intermediate point in one school and two other points in the other school.
9	Smith and Bitner 1993	N = 123 students Control: 63 Experimental: 60 Age: 14–16 Schools: 5	Uses Group Assessment of Logical Thinking (GALT) instrument of multi-choice items to assess understanding. Data gathered pre- and post-intervention.
10	Smith and Matthews 2000	N = 60 students Control: 23 Experimental: 37 (questionnaire) Control: 4 Experimental: 8 (interviews) Age: 15–16 Schools: 1	Two questionnaires: (1) 25-item Likert-type questionnaire on perceptions of school science and science; (2) 21-item Likert-type on students' perceptions of science teaching. Interviews: to gather views on school science, science and science teachers. Data also explored for gender effects. Data gathered post-intervention.
11	Tsai 2000	N = 101 students Control: 49 Experimental: 52 Age: 15–16 Schools: 1 Data collected from subset of 20 students in each group.	Focus on modules on light, electricity and nuclear energy. Interviews with 20 students selected randomly from each group to establish what they had learned from their instruction. *Note:* Study also used a Likert-type instrument to assess Science Epistemological Beliefs (SEBs). Interview data gathered at three points during the intervention.
12	Wierstra 1984	N = 398 students Control: 144 Experimental: 254 Age: 15–16 Schools: no details	Focus on one four-week module on *Traffic*. *Understanding:* Physics achievement tests from PLON and traditional physics exams. *Attitude:* 12 item Likert-type questionnaire. Also: 10-item Individualized Environment Questionnaire to assess student perceptions of learning environment. Data also explored for gender effects. Data gathered post-intervention.
13	Wierstra and Wubbels 1994	N = 464 students Control: 209 Experimental: 355 Age: 15–16 Schools: no details	*Understanding:* 19-item multiple choice standard physics tests. *Attitude:* 12 item Likert-type questionnaire on responses to school science. Also: 10-item Individualized Environment Questionnaire to assess student perceptions of learning environment. Data gathered post-intervention.

(Continued)

	Study	*Evaluation sample details*	*Summary of evaluation design*
14	Winther and Volk 1994	N = 93 students Control: 51 Experimental: 42 Age: 15–19 Schools: 1	A standard test of achievement in chemistry was administered pre- and post-intervention.
15	Yager and Weld 1999	N = 6590 students Control: 1320 Experimental: 5270 Age: 12–14 Schools: from five school districts	*Understanding:* Test instruments from the *Iowa Assessment Package*, that gathers data in six domains including concept (i.e. understanding) and attitude. *Attitude:* see above. Data also explored for gender and ability effects. Data on understanding gathered post-intervention. Data on attitude gathered pre- and post-intervention.
16	Zoller et al. 1990	N = 473 students Control: 276 Experimental: 101 Age: 16–17 Schools: 6	Four Views on Science-Technology-Society (VOSTS) items. Data also explored for gender effects. Data gathered post-intervention.
17	Zoller et al. 1991	N=577 students Control: 255 Experimental: 302 Age: 16–17 Schools: 6	Six Views on Science-Technology-Society VOSTS items. Data also explored for gender effects. Data gathered post-intervention, but also gathered from 96 students only part way through the intervention to give a form of pre-intervention data.

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3. PLACE-BASED LEARNING ENVIRONMENTS

Environmental Education in Teacher Education

INTRODUCTION

With climate change, loss of biodiversity and overfishing catching the headlines almost daily in social media, the general public has directed its attention to early childhood and K-12 education to lead the paradigm shift needed to right the wrongs, while also preparing future generations with the skills needed, such as critical thinking and problem solving, to resolve the impeding environmental and social issues that they will confront. Unfortunately, there is inadequate support for in-service and pre-service teachers in teacher education programs in Canada, and around the world, on integrating environmental education into their classrooms. The Faculty of Education at Simon Fraser University in British Columbia, Canada has been offering an environmental education summer institute since 1971, providing an opportunity to inform environmental education in teacher education.

This chapter aims (1) to shed light on environmental education in teacher education by attempting to understand the role of the learning environment in such programming; and, (2) to validate an alternative methodology to evaluate environmental education programs in teacher education. This chapter begins with a brief description of the environmental education summer institute in the Faculty of Education at SFU, place-based education and learning environment research. Following that we provide details on the methods used in this study, with a discussion on our interpretations of what the results tell us about environmental education and learning environments. Finally, the method used for mapping the learning environment will be discussed as a way to explore its value for environmental education.

BACKGROUND

Environmental Education at Simon Fraser University

The Faculty of Education at Simon Fraser University has a long and rich history of environmental education (EE). The Environmental Learning and Sustainability Academy – ELSA (previously known as the Summer Institute in Environmental Education) is now reaching its 43rd year of offering EE programming in teacher education at SFU. From its inception in 1971, ELSA faculty have worked closely

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with practicing, in-service teachers and with faculty from a range of disciplines within the university and the general community to offer an EE course during the summer semesters at SFU. ELSA now has two offerings: EDUC 452 – Environmental Education (Metro Vancouver) and EDUC 452 – Environmental Education (Haida Gwaii) by SFU's faculty of education. For clarity, EDUC 452 – Environmental Education (Metro Vancouver) was based in the Metro Vancouver region; and EDUC 452 – Environmental Education (Haida Gwaii) was based in Haida Gwaii, an archipelago off the British Columbia Pacific coast.

Place-Based Education

The leading descriptive curriculum theory (i.e. how things should be or are taught) that is at the foundation of ELSA is that of place-based education. Sobel (2004, p. 7) best explained place-based education and its relationship with environmental education as:

> The process of using local community and environment as a starting point to teach concepts in language, arts, mathematics, social studies, science, and other subjects across the curriculum. Emphasizing hands-on, real-world learning experiences, this approach to education increases academic achievement, helps students develop stronger ties to their community, enhances students' appreciation for the natural world, and creates a heightened commitment to serving as active contributing citizens. Community vitality and environmental quality are improved through the active engagement of local citizens, community organizations, and environmental resources in the life of the school.

The theoretical tradition of place-based education is not its own, but a bricolage of those belonging to contextual learning, constructivism, experiential learning, problem-based learning, as well as others that share in emphasizing the value of learning from one's own community or region (Gruenewald, 2003). Place-based education is "designed to help students learn about the immediate surroundings by capitalizing on their lived experiences" (Knapp, 2005, p. 278). Smith (2002), and Woodhouse and Knapp (2000) have both spent considerable time to identify common forms and characteristics of place-based education. Smith (2002, p. 593) noted a number of shared traits among programming that has been identified as place-based education: (a) surrounding phenomena are the foundation for curriculum development, (b) an emphasis on students becoming the creators of knowledge rather than only consumers of knowledge created by others, (c) students' questions and concerns play central roles in determining what is studied, (d) teachers act primarily as co-learners and "brokers" of community resources and learning possibilities, (e) the walls between the community and school buildings are crossed frequently, and (f) student work is assessed based on its contributions to community wellbeing and sustainability. Woodhouse and Knapp (2000, p. 1) claim that place-based education curricula have the following common characteristics: (a) the curriculum content is multidisciplinary; (b) the curriculum goals are broader than just “learn to earn;” and (c) the curriculum integrates self, others, and place and includes ecological, economic, multigenerational, and multicultural dimensions.

LEARNING ENVIRONMENT RESEARCH AND ENVIRONMENTAL EDUCATION

The study of learning environments is a growing field of academic inquiry and although it is most prevalent within science education, it has application possibilities in many different areas and is particularly applicable to inter – or multi-disciplinary fields of study such as environmental education. A few observations, relevant to the present study, are important to make here.

First, from learning environment research, there is compelling evidence to suggest that the classroom environment has a strong effect on student outcomes (Fraser & Rentoul, 1980; Wang, Haertel, & Walberg, 1993; Fisher & Khine, 2006). Fraser and Rentoul (1980) did a study on person-environment fit looking at cognitive achievement and preferred-actual classroom environment congruence. What their results showed was a strong fit between high achievement and students being in an actual learning environment that matched their preferred learning environment. At the same time, research in regular science classroom shows that there is often a large distance between the preferred and actual classroom, with the actual classroom being perceived much less positive than the preferred one. In any case, when mapping place-based learning environments, it is important to map perceptions of both the actual as well as the preferred learning environment.

Second, Fraser (1998) makes the comment that students are an invaluable resource for learning environment analysis in schools and university classrooms because they have been exposed to many different learning environments throughout their schooling. While an observer’s perspective is an important tool in studying a classroom, the subjective and personal view of a student’s is lost by direct observation alone. Thus, unknown influential factors of learning in the classroom environment can be lost or unobserved. For the present study, this means that student perceptions were taken as the central source of data for evaluating the place-based learning environments; these perceptions were mapped both in a structured way via questionnaires as well in a more open way via group interviews (focus groups).

Third, learning environments research has developed a range of instruments for mapping students’ and teachers’ perceptions of the learning environment (Fraser, 2007), encompassing both more traditional elements of classrooms as well as more contemporary elements that fit better with the principles and background of place-based education, such as constructivist notions, collaborative learning, student-centered learning. For the present study it is important to select and incorporate classroom learning environment elements from past learning environments research that fit with these principles and that at the same time have proven to be reliable and valid for a range of contexts.

At this moment in time there does not exist a reliable measure to describe learning environments and environmental education in teacher education. Therefore before we can understand the relationship between learning environments and environmental education, a number of questions must be answered:

1. How might teacher education learning environments using a place-based pedagogy be characterized, described or validly measured quantitatively?
2. What differences exist between actual and preferred environments in teacher education classrooms using a place-based pedagogy?
3. How might teacher education learning environments using a place-based pedagogy be characterized or described?

METHOD

This study utilizes a mixed methodology that incorporates both qualitative and quantitative research methods. The selected participants for this study were two environmental education courses in a teacher education courses at a Canadian University. The courses were part of the Professional Development Program (PDP), which participants take as part of their teaching certification. The two PDP courses each had 24 students; one took place in an urban and semi-residential setting (Course 1), and the other in a rural and residential setting (Course 2). Within these courses the environment is looked at as a broad over-arching theme and so can be perceived simultaneously as a subject, an object or a topic. Educators are asked to consider where environmental education can be integrated across diverse curricula and practices. All students and teachers voluntarily participated in the study, and the relevant university research ethic protocols were followed. Data collection included administration of quantitative surveys, focus groups and participant-researcher observations.

The questionnaire selected for this study was Place-based and Constructivist Environment Survey (or PLACES). It had been tested and proven to be reliable in measuring learning environments in a variety of secondary classrooms (Zandvliet, 2012). As the questionnaire is not time or age sensitive, the questionnaire was easily adapted for use in post-secondary classrooms. The eight scales incorporated into the PLACES instrument were adapted from the previously referenced inventories and were derived from data that emerged from a series of focus groups with environmental educators. PLACES is a compendium on constructs that were viewed by place-based and environmental educators as being most important for their practice (Zandvliet, 2012). These eight scales are listed in Table 1.

The PLACES questionnaire also has two versions: (1) an actual and (2) a preferred one. The Actual-PLACES questionnaire has the students reflect on their experiences in an actual learning environment, while the Preferred-PLACES questionnaire has the students contemplate what their ideal, or preferred, learning environment would look like. As an example, the ninth statement in the Preferred-

Table 1. Sample statements from the selected scales for the PLACES questionnaire

Subscale	*Sample*
Relevance/Integration (RI)	I want my lessons to be supported with field experiences and other field-based activities.
Critical Voice (CV)	It would be ok for me to speak up for my rights.
Student Negotiation (SN)	I want to ask other students to explain their ideas and opinions.
Group Cohesion (GC)	I want students to get along well as a group.
Student Involvement (SI)	I want to ask the instructor questions when we are learning.
Shared Control (SC)	I want to help instructors plan what I am to learn.
Open-Endedness (OE)	I want opportunities to pursue my own interests.
Environmental Interaction (EI)	I want to spend most of the time during field local trips learning about my environment.

PLACES that students are asked to contemplate is: '*It would be all right for me to express my opinion*'; the ninth statement in the Actual-PLACES that students are asked to reflect on is: '*It's all right for me to express my opinion*'. The statements are nearly identical but one is in the future conditional (preferred) while the other is written in the present tense (actual).

These two forms of the PLACES questionnaire have value on their own and when together. The Preferred-PLACES can be used as a diagnostic tool at the beginning of the course to understand the expectations of the students. The Actual-PLACES can act as an evaluation tool at the end of a course to see if the students had enjoyed their learning environment through the course. Together, these two forms of the PLACES questionnaire can be compared with one another to see if a student's preferred learning environment was actually the learning environment they were in, or better put they can aid in the research into person-environment fit interactions. For more information on the PLACES questionnaire such as scale reliability please refer to Zandvliet (2012).

On the first day of the course each student was asked if they would complete the Preferred-PLACES questionnaire, and on the last day of the course each student was asked if they would complete the Actual-PLACES questionnaire. To evaluate the questionnaires each statement was coded, following a Likert-type scale, from *never* (1) to *always* (5), and if a student left a statement unanswered the statement was rated as equivalent to a neutral score (3). Validity and reliability data were calculated for this sample.

Further data was collected qualitatively via focus groups and followed a phenomenographic study structure. The argument for this was that the information gathered from the students during focus group sessions could be compared with the data gathered from the questionnaire to corroborate its findings and to deepen these descriptions of educational experience. Five students (approximately 20% of the class total) were asked to volunteer from each class to take part in a focus group. From all students that volunteered to participate in the focus group interview, we took the first five students. During the interviews the researcher recorded detailed notes of the discussion. The quotes from the students in this project as such are not their exact words, but have been paraphrased while trying to remain as accurate to the students' original comments. During the analyses of the results, conclusions drawn by the first author (and instructor of the course) were checked and verified by the second author (not involved in the course directly). In case of disagreement, the two authors discussed until they reached consensus.

Focus groups were conducted at the beginning of the course and again at the end. At the beginning of the course, the focus group was asked two open-ended questions:

- What were your reasons for taking this course?
- Do you have any expectations of this course?

At the end of the course, the focus group was asked two other open-ended questions:

- Taking into consideration your expectations at the beginning of the course, did this course meet those expectations?
- Is there anything else you would like to comment on with regards to this course?

These questions were selected based on their generality and openness, therefore allowing the opportunity for any of the eight scales to be discussed in the focus group without having to be asked directly.

RESULTS

In this section we will present the results from observations as participant-researchers in the two courses as well as the results from the PLACES questionnaire and the focus group interviews. The two courses are characterised by their different respective locations. Results are presented within the context and description of each course section studied to detail a concise case summary of each study location.

Description of the Learning Environment

Vancouver-based PDP summer institute in environmental education. The first day of class was in some way aimed to create a comfortable group dynamic among the newly introduced class. The instructors had asked students to bring in an environmental artefact, which was to be something that belonged to them, whether it is a story or an object that was special to them and reflected their connection to the environment. All students were given as much time as they wanted to talk about themselves and their environmental artefact. It should be mentioned that the room was organized in a way that everyone could see each other's face and did not place the instructors in an authoritative position.

The following activity had the students work in groups with the objective of deciding when their class assignments were due. For specific reasons a few exercises had been selected by the instructors because of specific activities that were dependent on them. For instance, a presentation on their final project had to be on a particular day because there was an event that revolved around those presentations elsewhere. This example of sharing the control of the course structure took some students by surprise. It seemed that instructors giving students the opportunity to choose their own assignment deadlines is not at all common. Some students took advantage of this, while others did not care to participate, because to them it made no difference. After a set amount of time each group came back together as a class and the instructors asked each group what were the recommended deadline dates for the assignments. Not surprisingly, everyone did not come up with the same dates and then a discussion emerged in the course. This exercise in sharing the control of the course also turned into a group exercise whereby students had an opportunity to voice their rationale on their or their groups decision. We have to remember this was the first day of the course, and already by midday we have students who have already presented the personality that goes with their name by the use of the environmental artefact and working together for the common good of the group, the deadlines of their assignments.

The next activity was one that had the students working in groups again to take part in a scavenger hunt. The hunt had the groups find out information on their local environment and surroundings. Afterwards each group was asked to present on what they had found on the scavenger hunt. From this researcher's own experience, activities like the ones just mentioned do not occur in post-secondary classrooms. While it could be argued that in large two hundred student first year undergraduate classes these types of "bonding" activities are just not possible, this does not mean that the activities are not practical. While there was some discussion on environmental educational theory, the majority of the first day of class had been used as a 'get to know' session as were the next few days. The course took a field trip together, learning about their local port on their way to a camp/lodge site where they stayed the night. At the camp/lodge site a number of learning activities took place. At the end of the three days of class, the course had emphasized the creation of a good group dynamic, encouraged discussion between students and their peers. Reflective of this, a student in the focus commented:

> After the field trips and their experiences I missed the people in our class and so I looked forward to each class to reconnect.

The remaining weeks in the course seemed to follow the same format, an emphasis on group work and discussion whilst participating in outdoor activities. Other field activities included visiting local parks, water reservoir, sewer plant and garbage dumps, with each setting having its own associated lesson plan. It was one of these activities that had one of the students comment:

> The selection of experiences chosen by the instructors had a lasting effect. I had not expected to be as affected as I realize now at the end of the course. I plan to go back to the places we visited.

From our perspective, the settings chosen to correspond with specific activities were effectively thought out by the instructors because of the apparent effect it had on the students. Even though some of these students had previously been to the selected outdoor settings, it was the context that they were put in by the instructors that seemed to stimulate reflective thought within the students. It seemed to have stricken a chord in some students, as this one student commented:

> Before this I was a consumer with little consideration for the environment; this class has now changed who I am, and how I view the planet. I was so affected by the experiences we had that I wish the class was longer so I could have time to absorb it all.

The critique of needing more time to absorb the experiences was also voiced by another student in the course who also was quite affected by the activities:

> The course reminded me of the significance of each action. My only criticism is that I would make the class longer so we could have more reflection time.

The two instructors presented themselves as approachable and welcoming, as well as aiding students to find a solution rather than giving them the solution. The comfort with the teachers was quite apparent with students, by the visual evidence of the teachers being in discussion with students during breaks or at the end of classes. A level of humour was also present, created by the two instructors, which can only be a plus for any type of learning environment. This was commented on in the final focus group:

> I appreciated the openness and freedom that the instructors created in the course, especially with the portfolio exercise. I also appreciate the resources the instructors used since it wasn’t all about science but how to integrate the environment and that helps me with teaching.

The reference to a portfolio exercise was example of flexibility in the course assignments. The final assignment was a journal, or alternatively a portfolio, which was to be created by the students to embody what they had learned in the course. The portfolio could take any form, and while this freedom did intrigue some, others were lost by this opportunity. It seemed that some students struggled with the notion that they were allowed to present what they personally felt they had learned from the course, rather than taking the customary written exam. We observed that the same students who at the start were struggling with the concept of a portfolio, at the end created some of the most memorable ones. The presentations of the portfolios took place at a camp/lodge at the end of the course, much the same way the course had begun. On the last day, before the class officially ended, the researchers met with the focus group and one profound and lasting comment by a student was:

> The environment created provided open learning and provided me with the freedom to learn. I realized that environmental education has the potential to help children and adults understand where they are. I realize now that environmental education is my thing.

We personally feel that this statement was representative of the majority of the students. Even if it was just isolated to this one student, a statement like that by one student alone, we believe, is what we all teach for.

Haida Gwaii-based PDP summer institute in environmental education. Similar to the Vancouver- based course, Haida Gwaii-based PDP Summer Institute in Environmental Education first class occurred in an educational institution. The only difference was that the Haida Gwaii-based course was busy during the first day setting up their sleeping tents in classrooms, while the Vancouver-based course was sitting in discussion. The reason for this was that for the duration of their course in Haida Gwaii the students were to share the secondary school as their home. Therefore, getting to know your fellow students was not an option but rather mandatory for the purpose of the course. The first day ended with a class get-together in the evening playing a name game for everyone to introduce themselves and a small discussion of the course's syllabus. The next few days of the course incorporated similar activities and exercises to those of the Vancouver-based course. The environmental artefact and the assignment deadline activity played a similar role in helping to create a good group dynamic. Of course in this setting, because they lived together, these two activities were not the only way for students to get to know one another at a personal level. For this reason it was not surprising to see that these students had scored Group Cohesion as their highest scale in the Preferred-PLACES questionnaire. This also led a couple of students, when reflecting back, in the final focus group to say:

> The living accommodations at the school created a type of community with everyone in the class. I felt it was a lesson in being tolerant and understanding of other people.
>
> I learned a lot that I did not expect, things that I had not associated with environmental education, such as group dynamics through spending time together in our living accommodations at the school as well as on our camping trips.

Although the students had got to know one another quite well after the first few days, they were still strangers; strangers to the very environment they were living in, Haida Gwaii. The activity that was chosen to remedy this was called 'community mapping'. This exercise had also been an activity included in the Vancouver-based course. But with this course it had a different impact on the students and in the author's perspective a much more powerful one on the learning environment. This was another activity conducted in groups. Group membership was something that was watched by the instructors. While there were times when groups were allowed to be formed on their own, there were also some activities where groups were formed by the instructor in order to inhibit the emergence of cleeks and for everyone to be a part of a different group of people. The community mapping activity entailed groups collecting information on the socio, techno and ecosphere of a community. To do so the groups spent the whole day in their given community to collect information on the community whichever way they pleased. From the perspective of a participant-observer in this course, there was a visible change in the comfort zone of the students in their new environment before and after this activity. Students returned at the end of the day with stories, information and objects from their respective communities. They were energetic to present and recount how their day went. It was remarkable to see how excited these students were conducting and presenting on this activity. These post-secondary students in some ways bared resemblances to young elementary students with their energy for learning. Now while this activity was primarily place-based in theory and one of the reasons it was integrated into the course, this activity had a much more profound effect because these students were visitors to Haida Gwaii. This was mentioned by one of the students in the focus group:

> The community mapping exercise was the highlight for me of the course because I no longer felt like an outsider in the community, which made my stay in Haida Gwaii much more enjoyable and memorable.

One result from this community mapping exercise was an invitation by the Haida Nation to the class to go out in their traditional canoe that had been created by Bill Reid, who is a well-known First Nations artist of the Pacific Northwest. This invitation came about when a group went to the community of Skidegate for their exercise and began to interview people in that community. This invitation was by no means something that happens regularly. The canoe had not been in the water in over six months and was about to be placed in the Haida Heritage Center. This was an honour not only to take the canoe out in the water but also to be one of the last few people to be able to do that. This was not something that was missed by the students in the course:

> On a personal level the bonuses in the course, such as canoeing in Bill Reid's canoe and learning about the Haida culture, were experiences that were not expected and I am appreciative for them.

Connecting to the people living in Haida Gwaii, especially the Haida Nation themselves, was one of the objectives set out by the instructors. When possible, the instructors referred to examples in the Haida culture or in Haida Gwaii when discussing course material. When talking about activities, every excursion that took place occurred in a place that held historic and present value to the Haida people.

A two-day trip was organized through Naikun, which is also referred to as Rose Spit in Naikoon National Park. This excursion took place on the second week, and had been chosen by the instructors to develop a spiritual and ecological sense of place in their students. The second large outdoor activity was a five-day hike and kayak trip from within the Cumshewa Inlet to Gray Bay. The Cumshewa Inlet is named after the old Haida Cumshewa village which was a stop on the kayaking part of the trip. Another old Haida village site that visited on this trip was one Skedans found just outside the Cumshewa Inlet on the Hecate Strait coastline. Due to complications with a tour company the class almost did not visit the Skedans village site, which for some became the highlight of this 5-day adventure. Ironically, what was first a complication became a lesson to the group. The tour operator who was taking us by boat to the Skedans site had tried to convince the group that this site was very similar to the Cumshewa village in an effort, in my belief, to save their time and money. The tour operators attempt did not work on the class, and everyone visited the Skedans site the next day. While at the Skedans site and afterwards numerous comments were made by the students in the class with regards to this site having a very spiritual and warming feeling, which has not been apparent at the *Cumshewa* village site. In no way were the Cumshewa and Skedans villages the same. The actions by the tour operator illustrated the disconnection of someone who just lives 'on' Haida Gwaii and not someone who really lives 'in' Haida Gwaii. The tour operator had no sense of place even though they lived 'on' Haida Gwaii. This is a conclusion that many of the students came to as well from the remarks that were made to the researchers during our time there. We would like to think this reaction by the students was visible evidence that the exercises during the course, and the extracurricular activities that came from them, had effectively created the sense of place with Haida Gwaii that the instructors had aimed for. A comment by one student in course referred somewhat to this point:

> While I had taken courses on First Nations history and culture, I feel I gained a deeper understanding of the Haida people because of this course.

For some, this sense of place of Haida Gwaii and to the Haida people became so strong that they argued that the course could have been more place-based.

> I feel the class could have been more place-based, such as some of the assignments could have been more tailored towards Haida Gwaii.

While this comment by one of the students may appear to be a critique of the course's structure, we feel that this comment came to fruition because of the same structure that is being criticized. The student that made this comment was also one of the students who, at the first focus group, had said that they had taken this course because it was an 8-credit course and their friend was also taking the course. Not once did this student infer that they were taking this course because they wanted to learn more about place-based education. Nor did they show interest in wanting to learn about the Haida people. It was only at the end of course, after the Haida-centered activities, did this student acknowledge place-based education and the Haida Nation. Therefore, the critical comment, in our belief, showed that this student had grasped the theory of a place-based pedagogy and now in some ways was 'thirsty' for more. A number of the students, reflecting on the above outdoor activities as well as the exercises in the course, commented positively on the courses structure:

> The exercises and activities chosen by the instructors helped me understand and learn about what environmental education and place-based education are.
>
> The outdoor experiences we had put the environmental education theories we learned the first week into practice.

The relationship between the students and the instructors was a close one because of the amount of time that was spent with one another. That being said, being social everyday can be tiring but the instructors always appeared enthusiastic. As one student commented:

> I felt comfortable with the [instructors]. They were personable; they never lectured and always treated me as their equal.

With regards to how this translated into how the class was taught, it appeared students felt free and comfortable. There was not a feeling that you were being judged or graded on every move you made or every comment or question you asked. This openness allowed for some great discussions not only at times when the class was indoors but also when they were outdoors. Personal freedom was also evident in the group and individual exercises of the course. As an example, one group assignment was to read over an article and then present and summarize the article's main points but no one was told how they were to present it. Students took advantage of this and came up with some memorable presentations, such as a rap song and a Shakespearean-like play. A few students commented on this flexibility in the class:

> I like how the instructors did not push students and did not act as an authority figure. They were supportive and I felt like they were more colleagues than instructors, and they allowed the students to figure things out on their own.
>
> I liked how the instructors allowed the students to explore things on their own, [and] were knowledgeable and were always accessible.

While most students in the focus group were quite positive, the course was not left without its critics. Two students commented that they had wished there had been "more discussions about environmental education in the classroom around the campfire" and on "how to apply direct experiences and activities to our own classroom". One of the students went into more detail, explaining the way they felt:

> Maybe the creative people were able to grasp how to implement environmental education into the classroom but for the non-creative person there is a need for discussion on how to apply it.

This comment, in some ways was countered by another student in the focus group who claimed that "I now see the other point of view. I am no longer seeing through the eyes of a student but now through the eyes of a teacher". This same student then went into detail of what they had learned in the course:

> It seems much better to take a student out into the field first to experience things with little knowledge of what there is outside and allowing them to have their own personal discoveries and discover their interests in nature. I believe the student will come back to school and have an interest in learning more of the environment that they had just experienced.

The student who had made the previous critique, made a comment to the researcher that because of this trip they appreciated camping at the beach more, and they plan to do more of it. This pre-service teacher had already taken out a class of elementary school children to the mountains around Vancouver during their teaching practicum. With that said, this new teacher may now pass on this new appreciation for the beach and ocean to their students.

The end project was also a portfolio that could take any creative form. Once again, there was some curious confusion with what exactly the portfolio could be. In the end this brought about unique and personal interpretations of what it was that they learned. Some in fact brought a number of students to tears, which should indicate to the reader the type of environment that had been created during this four-week course. A parting comment made by one of the students in the focus group acknowledges this learning environment:

> The environment created by the instructors while on Haida Gwaii epitomizes what environmental education is to me. Now that I think of it, this class exceeded my expectations.

PLACES QUESTIONNAIRE

The calculated values from the Cronbach alpha and discriminant validity from the PLACES responses in Courses 1 and 2 indicated that the eight constructs in both of forms of the questionnaire demonstrate acceptable within scale reliabilities but also validly measured eight distinct constructs (Table 2). The PLACES questionnaire does validly measure learning environments in post-secondary classrooms that use place-based and constructive pedagogies.

The mean scale responses from Course 1 (Figure 1) and Course 2 (Figure 2) from the Preferred- and Actual-PLACES questionnaires indicated that there was no apparent difference between preferred and actual learning environments in these settings. The actual learning environment that the two instructors created in Courses 1 and 2, using place-based and constructive pedagogies, not only met the students' expectations of their preferred learning environment but, in some aspects, exceeded them.

Table 2. Calculated values for reliability (Cronbach alpha) and discriminant validity for each PLACES scale

PLACES scale	*Cronbach's alpha*	*Discriminant validity*
Relevance/Integration	.76	.14
Critical Voice	.72	.21
Student Negotiation	.76	.38
Group Cohesiveness	.70	.23
Student Involvement	.70	.38
Shared Control	.86	.29
Open Endedness	.73	.24
Environmental Interaction	.70	.30

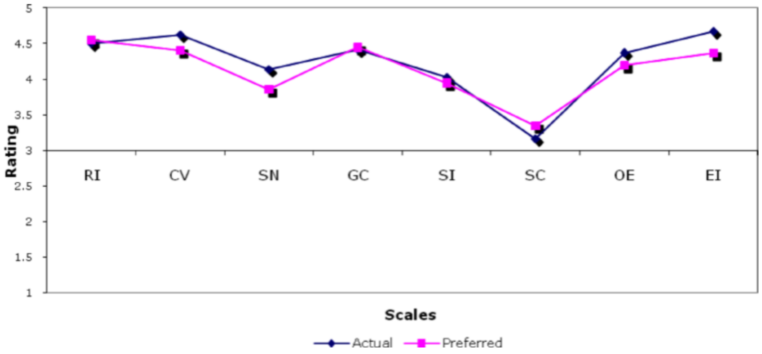

Figure 1. Learning environment comparisons from Course 1 Preferred- and Actual- PLACES questionnaires

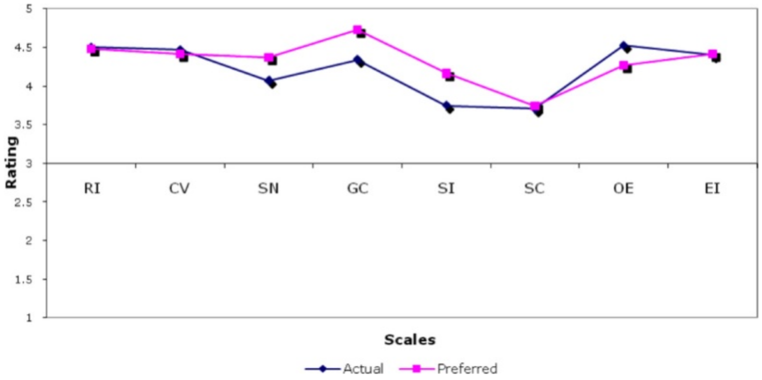

Figure 2. Learning environment comparisons from Course 2 Preferred- and Actual- PLACES questionnaires

DISCUSSION

Measuring and Comparing Learning Environments

One of the questions being asked in this research was ‘can aspects of the learning environment in teacher education classrooms, using a place-based pedagogy, be validly measured?’ After reviewing the data collected by the PLACES questionnaire and triangulating it with the information collected from the focus groups and participant-researcher observation we believe that the PLACES questionnaire can validly measure learning environments in post-secondary classrooms that use place-based and constructive pedagogies. Besides the commonalities between the responses from the questionnaires, their corresponding focus groups and participant researcher observations, there are also similarities between the responses to the Preferred-PLACES questionnaire in each course. While this questionnaire was not created to compare learning environments between the different courses, the results from the Preferred-PLACES can in theory be compared because at the time each course was taking the Preferred-PLACES questionnaire none of the courses had yet been exposed to their respective learning environments, thus they were all still representative of the same sample population, post-secondary students. With that said, the most striking similarity is that both courses perceived the scale of Shared Control as the lowest of all eight scales, while the scales of Critical Voice, Group Cohesiveness and Environmental Interaction were highly rated in both courses. Another observation that can only be clearly seen by looking at Figures 1 and 2; is that they all seem to share the same pattern (‘peaks’ and ‘valleys’) in their data sets. These similarities indicated to us that this questionnaire has been accurately created to measure these eight constructs of a learning environment that uses place-based and constructive pedagogies. To comment on the instrument’s performance, while the total sample size was comparatively small to make significant comparisons between preferred and actual scores, the sample size was suitable to test for reliability and validity of the constructs in each form of the questionnaire. The calculated values from the Cronbach alpha and discriminant validity indicated that not only did the eight constructs in both forms of the questionnaire demonstrate acceptable within scale reliabilities, but also validly measured the eight distinct constructs. With the strength of having statistical reliability and validity, and the commonalities between questionnaire, focus groups and observation, as well as the similarities between courses in their Preferred-PLACES results, we are confident that the PLACES questionnaire validly measures the learning environment in post-secondary classrooms that use place-based and constructive pedagogies.

A second research question asked ‘what differences exist between actual and preferred learning environments in teacher education classrooms using a place-based pedagogy?’. Current trends in learning environment research have noted that preferred and actual learning environments had a much closer fit in interdisciplinary, outdoor-based learning environments than single disciplined, classroom-based learning environments (Zandvliet, 2012). With this in mind, it was hypothesized that the results from these two outdoors-based courses would agree with this trend.

If we first examine the Vancouver-based course, the mean scale responses from the Preferred- and Actual-PLACES questionnaire were quite similar. Of the eight scales, only three of the scales (relevance/integration, Group Cohesion, and shared control) had lower scores on the Actual-PLACES questionnaire than those from the Preferred-PLACES, and their differences were only slight. The remaining five scales (Relevance/Integration, Critical Voice, Student Negotiation, Group Cohesion, Student Involvement, Shared Control, Open-Endedness, and Environmental Interaction) had higher mean scores in the actual questionnaire than that of the preferred. After looking over the results, it would appear there is no difference between the preferred and actual learning environment. The actual learning environment that the instructors created using place-based and constructive pedagogies not only met the students' expectations of their preferred learning environment but in some aspects exceeded it. This is quite a surprising result.

In the results from the Preferred- and Actual-PLACES questionnaires, from the Haida Gwaii-based PDP Summer Institute in Environmental Education, five scales (Student Negotiation, Group Cohesion, Student Involvement, Shared Control, and Environmental Interaction) had lower scores in the Actual-PLACES questionnaire than those from the Preferred-PLACES, and three of the scales had higher scores (Relevance/Integration, Critical Voice, and Open-Tenderness). Lest it be said, that the range in the differences of these five aforementioned scales was minimal, 0.02 (Environmental Interaction) to 0.42 (Student Involvement). To give this some scope, there is a general trend in current learning environment research showing substantially large gaps between preferred and actual learning environments in classroom-based courses (Zandvliet, 2012), much more than we see here in this field-based course. Taking this a step further, if we look at all eight scales they were on average 0.11 lower in the actual learning environment than in the preferred learning environment. This is not a large difference at all between the preferred and learning environments. These results paint us an interesting picture of a learning environment of an outdoors-based course that uses place-based and constructive pedagogies. As Figure 2 illustrates, these results indicate that there was a near match in preferred and actual learning environments in the Haida Gwaii-based course, and little difference in mean scores on each scale.

If we reflect now on the information recently provided on the results of the Preferred and Actual-PLACES questionnaires from both courses, we can come to the conclusion that the results here indicate that no difference was strongly evident between a student-preferred learning environment and an actual learning environment that used place-based and constructivist pedagogies. In the focus groups this was also the conclusion. As can be seen in the results from the focus groups, every student either stated that the course had met expectations or exceeded them, as it had with a number of the scales in the Preferred and Actual-PLACES questionnaire. These results agree with what is being currently found in other learning environment research. Field-based learning environments, using place-based and constructive pedagogies, appear to strongly fit students' preferred learning environments.

Describing Learning Environments

The third and last question posed in this research was 'how might teacher education learning environments using a place-based pedagogy be characterized or described?'. In the focus groups that took place at the end of course, a number of the students in the Vancouver-based PDP course made comments that could be perceived as referring to 'personal growth', such as "it provided the wakeup call"; "what it did was change my outlook on life"; "[it] moved me"; and "it was an awakening" . In contrast, the Haida Gwaii-based students made comments at the end of the course that referred to a type of 'pedagogical growth', even though a number of students at the beginning of the course had commented they had taken this Haida Gwaii-based course for reasons that could be construed as 'personal growth'. This is an important difference between these two courses especially since they had the same course objectives but were taught in different environmental settings and formats. We believe this is something that should be pointed out, the influence that a specific environmental setting has on a learning environment. The Vancouver-based course visited local water reservoirs, parks and dumpsites to name but a few. These environmental settings exposed the students to the sources and discharges that are a part of their daily life. As if they had been given a new sense, a 'sense of awareness'. This is what we believe brought about the comments on personal growth in the Vancouver-based students. The environmental settings in the Haida Gwaii-based course, on the other hand, were most often wilderness settings in attempt to expose students to a foreign environment and in doing, so rather than giving rise to a sense of awareness as with the Vancouver-based course, these students were 'awoken' to outdoor activities. These activities they could do with their own courses once they finish their PDP program. It is possibly for this reason these students made a number of comments that referred to 'pedagogical growth'.

CONCLUSION

Research on learning environments and environmental education is still in its infancy. Thus there is a need to continue similar research. Reflecting on the three research questions, it appears that we can validly measure quantitatively learning environments in teacher education classrooms using a place-based pedagogy with the PLACES questionnaire; there exists little difference in actual and preferred environments in post-secondary classrooms using a place-based pedagogy as shown in the results from PLACES; and, lastly, the characterization and description of teacher education learning environments using a place-based pedagogy is heavily influenced by its environmental setting, as experienced by the learner. The PLACES questionnaire was proven to be statistically valid and reliable, which has aided in establishing this questionnaire as an educational assessment tool. This opens up opportunities for future research to continue using the PLACES questionnaire in similar classroom environments, as well as the potential to adapt and evolve the PLACES questionnaire for other learning environment assessments.

With regards to environmental education, the comments made by the students in the focus groups appear to indicate that they are serious about integrating environmental education in their future classrooms. While positive, the question whether this interest is translocated to their classrooms once they graduate is something that needs to be investigated. The hope with ELSA and this study is that pre-service and in-service teachers will now see the important link between doing environmental education and creating a place-based learning environment.

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4. SCIENCE KITS

Learning Chemistry in a Context-Oriented Learning Environment

INTRODUCTION

Context-oriented learning environments place emphasis on students generating ideas and accessing specific aspects of content knowledge in order to solve problems from their real life (Pilot & Bulte, 2006). Implemented in a learning environment, collaborative and inquiry-based elements serve the purpose to support students in furthering their questioning and reasoning skills. The science kits presented in this chapter are supposed to satisfy these needs by providing student small groups with ready-to-use material embedded in a context-oriented problem assignment. Real life contexts can easily be implemented in the tasks accompanying the kits so that the underlying chemical knowledge is acquired on a need-to-know basis (see Chapter 1) while students are working together in the learning environment.

This chapter introduces a context-oriented unit on elementary acid-and-base chemistry which is based on five consecutive science kits. In the first part, the teaching context of German chemistry classrooms is discussed in light of the context-based movement and relevant theoretical background knowledge is provided. In a second part, the development of the kits is presented and selected empirical results on their efficacy are discussed with reference to issues of practicability in teaching. Thus, the chapter offers one possibility how context-based teaching may be implemented.

Context-based instruction has become a crucial element of German classroom instruction ever since the approach "Chemie im Kontext" (ChiK) has been introduced in the late 1990s (Demuth, Gräsel, Parchmann, & Ralle, 2008; Nentwig, Demuth, Parchmann, Gräsel, & Ralle, 2007). The ChiK-programme aims at encouraging teachers to innovate their teaching practice by collaboratively creating new context-based learning environments. So-called "teacher sets" were financially and intellectually supported to meet on a regular basis in order to develop learning modules which satisfied the needs of context-based learning (see Chapter 10). Based on a symbiotic approach in which teachers and developers intensively collaborate, the implementation strategy includes regular communication with science educators and school management. Materials are either developed together or discussed jointly in light of the different expertise.

Generally speaking, ChiK is based on a theoretical framework with three fundamental principles (Nentwig et al., 2007): (1) the teaching unit has to refer

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to a real life problem situation (the *context*) which is well-known to students and adds relevance to concept acquisition, (2) the learning environment should include methods which scaffold self-directed and cooperative learning in line with a constructivist approach to learning and (3) the real life context should enable the learner to systematically acquire basic chemical concepts by repeatedly referring to conceptual knowledge as well as subsequent 'decontextualisation'. Based on these three principles, ChiK teaching modules are usually subdivided into four different stages which are implemented in the teaching sequence: in a first step (the contact phase), students are confronted with the topic and asked to pose questions, while the other three phases are intended for planning (1), elaboration (2) and nexus (3).

One decisive characteristic of ChiK modules, however, is that they are not "teacher-proof" curricula. Whether the context-based learning environment actually succeeds, depends on teachers' efforts, because the structure of the lessons has to be determined and implemented by the individual teacher. Although the ChiK-programme provides guidelines and example modules, teachers have to make an effort in order to implement the respective module individually.

Through the introduction of national science education standards (KMK, 2005) and the compulsory core curriculum in 2008 (MSW NRW, 2008), attention was raised towards teaching with contexts which are now supposed to be a compulsory and integral part of general classroom instruction. As concluded by ChiK, contexts play a central role in acquiring conceptual knowledge: central themes serve as a starting point to acquire conceptual knowledge which is needed to understand the theme, a principle which has also become known as the "need-to-know" (Pilot & Bulte, 2006). Although the acquisition of science concepts still plays a prominent role, concepts are, however, to be acquired in close relation to real life contexts and therefore stress the aims of educating scientifically literate students (Roberts, 2007).

While ChiK learning environments are predominantly developed and implemented by teachers who showed a high degree of openness to reform, the new general standards made it necessary to raise teacher interest in the role of contexts in the curriculum. Not only the participating teachers have to be familiarised with the innovation but also the average chemistry teacher has to be convinced to introduce contexts into their chemistry classroom. Not surprisingly, the implementation of contexts into the classroom was and is faced with common teacher prejudices against the approach: Resistance to innovation but also the lack of time and resources are among the most frequent inhibiting factors (Bennett, Gräsel, Parchmann, & Waddington, 2005). Given this circumstance, it has become inevitable to provide the average teacher with context-oriented materials which are well-evaluated and can easily be implemented into the chemistry classroom. Ready-to-use science kits with pre-selected equipment and student assignments can be helpful to make implementation more easily accomplished by teachers in context-oriented classrooms. This chapter aims at presenting and evaluating a learning environment which can be used by teachers to implement context-based modules into their chemistry classroom.

SCIENCE KITS AS CONTEXT-ORIENTED LEARNING ENVIRONMENTS

The presented science kits satisfy the demands of a context-oriented learning environment with respect to the following aspects: (1) their problem-based nature allows real life contexts to be the starting points of an inquiry-based task, (2) their collaborative nature meets the requirements of a constructivist learning environment, and (3) their compact physical nature (entire equipment in boxes) makes them accessible as ready-to-use resources for teachers and, thus, decreases preparation effort. The kits are not advocated to substitute whole context-based units but serve as a valuable basis to be incorporated into a teaching unit at selected points. Therefore, two out of five learning kits in the area of acid-base-chemistry are introduced in this chapter whereas a rough outline is given on the other three kits. As all kits are structured according to the same principles and can independently be used in the classroom, this seems appropriate to provide the reader with more details on the selected boxes.

Inquiry-Based Tasks

Apart from the respective contextual embeddedness, the inquiry-based kit is developed as a collaborative and self-directed task. The approach is based on a peer-tutoring method called Group Investigation introduced by Sharan and Hertz-Lazarowitz (1980) which "emphasizes data gathering by pupils, interpretation through group discussion and synthesis of individual contributions into a group product" (Sharan, 1980, p. 250). Apart from general collaborative aspects, which also characterize other student group activities, the approach focuses on the investigation and interpretation of a problem situation. Studies have shown that hands-on activities are perceived as more valuable by students if the learning environment is developed in an inquiry-based way (Hofstein, Nahum, & Shore, 2001)

Student Collaboration

Another emphasis in the development of the kits is placed on their collaborative nature. Small groups of students work on the problem as a "community of practice" while being mutually engaged in the activity (Wenger, 1998). Empirical evidence shows that concepts can be better acquired if they are communicated while they are learnt (Johnson, Johnson, & Stanne, 2000; Lemke, 1990). The process of negotiating meaning by discussing observations, evidence and newly acquired scientific concepts serves as a valuable basis to interconnect knowledge from real life situations with subject-dependent conceptual knowledge and therefore offers a deeper basis for understanding.

Learning with experimental science kits provides students with the opportunity to engage in an inquiry-based task and chose their individual role to contribute to the success of the collaboration process. The individual student is free to work as, for example, an experimenter or note-taker and communicate the underlying thinking processes accordingly. In order to satisfy individual dispositions in collaboration processes, students are not assigned roles but given a choice of activities on the basis of the equipment contained in the science kits.

Role of the Teacher

During the activity, the teachers are supposed to be active observers of the process. The student-centred learning environment should enable teachers to step back and monitor their students' progress in the assignment without taking an active role in the communication process unless necessary. Thus, the control over the learning process is mostly shared by the "community of practice" rather than the teacher who is merely an observer and gets an opportunity to reflect on the students' progress.

Science Kits

The context-oriented science kits have been developed on the basis of preceding work in the research group where similar small group activities were implemented on the same chemical content (Rumann, 2005; Walpuski, Wahser, & Sumfleth, 2008). The kits are developed on the basis of theories of conceptual change (Posner, Strike, Hewson, & Gertzog, 1982; Treagust & Duit, 2008). Students' alternative conceptions in the field of acid-and-base chemistry are accounted for in the development of the boxes by either including them in the problem or addressing them in the material.

Each of the five science kits is structured according to the same principle. They can be integrated into the elementary science classroom as single entities or as a whole unit. Teachers serve as counsellors rather than instructors as they are supposed to let students work with the kits on their own but may assist if unanticipated problems arise. Safety comments are teacher-centred and placed before the kits are distributed. As all necessary material is contained in the kits, ready-packed boxes can easily be implemented into the science classroom. Every single kit contains (1) one problem card; (2) information cards and (3) equipment to conduct experiments (see Figure 1). Furthermore, students are asked to take notes on the inquiry process into a lab book provided for each student small group.

The *problem card* constitutes the core element of the kits as the context since it defines the application situation and the challenge (context) the students will be facing during the inquiry process, It is crucial that only after the problem card is read out aloud, students are supposed to commence with their activity. An exemplary problem card can be seen in Figure 2.

Whereas problem cards clearly refer to the context, a second type of card 'the information card only provides students with information about the underlying knowledge. These cards either give explanations on key terms in the field of acid-and-base chemistry or provide students with data necessary to conduct experiments

Figure 1. Contents of science kit

Problem card
In your box, you can find two corrosive detergents: drain cleaner and toilet cleaner.
If they get in contact with your skin, they can cause skin damage.
Find out how to make detergents less harmful using the materials in the box.

Please use the syringes to take liquids from the flasks and/or measure volume.

Figure 2. Exemplary problem card (translated from German)

and/or understand the underlying conceptual knowledge base like, for example, the pH scale.

The equipment in the boxes consists of glassware (e.g., micro test tubes), other laboratory equipment (e.g., syringes) and chemical solutions which are bottled in small plastic flasks. Although the selection of materials matches the necessary experimental equipment required to conduct the favourable experiment, students are provided with enough extra equipment to break new experimental grounds.

Exemplary Contents of Science Kits

The five kits take different real life phenomena as starting points each referring to a different aspect of elementary acid-base chemistry. As can be seen in Table 1, the kits are cumulative in that they build up the knowledge base on acids and bases. Concerning their application situation, however, different real life contexts are selected over the course of the unit. Only kit 2 and kit 3 refer to the same application situation, being harmful detergents.

Two science kits (No. 3 & 5) are based on the concept of neutralisation within different contexts and are therefore used as examples. Because the kits are targeted at elementary chemistry courses, deeper level acid-and-base concepts are not introduced or referred to. The distinctive common feature of kits 3 and 5 is the

Table 1. Overview of application situations and respective content knowledge

Context	*Content knowledge*
Kit 1	
Categorizing of household liquids (lime juice, vinegar, soap)	Indicator Acid, neutral and alkaline as properties of liquids
Kit 2	
Harmful detergents in the bathroom	pH value to determine the property of a solution (pH 7 = neutral, pH < 7 = acid, pH > 7 = alkaline)
Kit 3	
Making harmful detergents less harmful	Neutralising an acid solution with an alkaline or vice versa
Kit 4	
Soda makers and the property of water	Solubility and property of gases dissolved in water
Kit 5	
Treatment of acid football soil	Neutralising an acid solution with solids which have alkaline properties if dissolved in water

cumulative acquisition of content knowledge in the area of neutralisation embedded in two different contexts: While kit 3 introduces neutralising a liquid agent with another liquid agent and refers to making harmful household liquids less harmful, kit 5 additionally incorporates the properties of solids being dissolved in water and refers to the treatment of acid football soil with solids that show alkaline properties if dissolved in water. Both kits are introduced in detail in the following section.

The first kit on neutralisation (kit 3) takes harmful household liquids as a starting point (see Figure 2 above) and is based on the alternative conception of students that acid and alkaline solutions may be made less harmful by purely diluting them with neutral solutions (e.g. water). Students are supposed to hypothesize that either water or sugary solutions (second alternative conception) help to make the detergents less harmful. In order to open up different inquiry procedures, all possibilities of solutions are provided in the kit and enough materials to conduct several experiments are included. The box contains the materials shown in Table 2.

As the syringes are graded and allow the measurement of the volume of liquid added, these will help students think about the relationship of the pH value and the volume of the solutions. They serve as a hint to further elaborate on the conditions that have to be met in order to neutralise the respective solution.

The inquiry process can be called successful if students conclude that equal volumes of acid and alkaline solutions which are equally distant from pH 7 lead to a neutral solution. Furthermore, students may already be able to vary the two variables *volume of solution* and *distance from pH 7* in order to neutralise the solution.

The second kit on neutralisation expands this knowledge base and serves as a valuable basis to revise and deepen the knowledge on neutralisation. As can be seen

Table 2. Materials contained in science kit 3

Solutions in plastic flasks	
	• Drain cleaner (diluted; alkaline solution) • Tap water • Sugary water • Toilet cleaner (diluted, acid solution) • Indicator solution
Equipment	
	• 4 disposable syringes (5 mL) • 8 micro test tubes • 1 small beaker • 1 non-permanent marker • Napkins • Rubber gloves
Cards	
	• Problem card • Information card: *pH scale* • Information card: *Indicator colours* • Information card: *What is a neutralisation?*

in Figure 3, students are supposed to make acid football soil neutral. However, this time the alkaline solution still has to be produced from a range of different solids which show different properties if dissolved in water.

Problem card

Acid rain results from air pollution: gases emitted by cars or factories are dissolved in rain and change the pH value of wet soil.
Grass as in football turf, however, grows best on neutral soil. Because of this, it is advised to treat the soil with a solid.

1. Find out which solid is most appropriate to treat the soil.
2. If you can use more than one solid, find out which properties they have and how they are called as a group.

Figure 3. Problem card in science kit 5

As can be seen in Table 3, students get an acid solution – representing the acid football soil – and four different solids. In line with kit 3, two solids (sugar and salt) refer to student alternative conceptions, while the other two (calcium and magnesium oxide) show alkaline properties if dissolved in water.

Table 3. Materials contained in science kit 5

Solutions (plastic flask) and solids (snap cap vial)	
	• Acid rain (acid football soil)
	• Sugar
	• Salt
	• Lime (Calcium oxide)
	• Magnesium oxide
	• Tap water
	• Indicator solution
	• Indicator sticks
Equipment	
	• 8 micro test tubes
	• 4 small beakers
	• 1 pipette
	• 1 spatula
	• 1 non-permanent marker
	• Napkins
	• Rubber gloves
Cards	
	• Problem card
	• Information card *pH scale*
	• Information card *Indicator colours*
	• Information card *Decanting solutions*
	• Information card *Oxides*

Students are supposed to apply their prior knowledge on acids-and-bases in general and neutralisation in two steps: first by testing the pH value of the “acid rain” and the solution resulting from dissolving the presented solids in water and second, by producing an alkaline solution whose pH value is as distant to pH 7 as the acid solution. By doing this, students reapply their knowledge on neutralisation and at the same time further their knowledge by getting to know solution processes of metal oxides.

EVALUATION OF SCIENCE KITS

The five kits were evaluated in an experimental study with the aim to compare the efficacy of context-oriented learning and adequate revision activities (Fechner, 2009). The study took place at seven different secondary schools in North Rhine-Westphalia, Germany, with 286 students in an elementary chemistry class (7th grade, 12 to 13 years). All students participated in the study on a voluntary basis so that most of them entered the project with a relatively high prior interest in the subject. Furthermore, students were allowed to form their own small groups so that motivational factors did not interfere with interest in the activity. It has been shown that collaboration processes are most successful if students can choose their collaboration partners to form small groups (Barron, 2003). Data on teacher variables is limited to observation of small group work.

Student Interest in the Concept of Neutralisation

In order to measure student interest as determined by the context-based environment, control kits were developed which used an inquiry-based scientific context as referents to compare interest levels. The control kits were developed in line with the respective context-oriented environment in their level of collaboration and inquiry-orientation. However, the problem situation is placed in the laboratory rather than a real life situation. All situations refer to the phenomenon of neutralisation as neutralising an acid solution with the help of an alkaline solution.

Questionnaires on situational interest levels were administered to students immediately after they had completed their task and a subsequent revision activity. Situational interest scales are subdivided into whether students were interested in the topic (problem task) or whether students liked the activity (experiments). Furthermore, students' perception of group collaboration was retrieved. All items were scored on a 4-point Likert scale (1 = I strongly disagree, 4 = I strongly agree)

Table 4. Descriptive results and group comparisons (t-tests)

		Topic-related interest	*Interest in the activity*	*Perception of collaboration*
Kit 3	Real life	2.67 (0.80)	3.38 (0.60)	3.21 (0.68)
(control)	Laboratory	2.30 (0.69)	3.25 (0.58)	3.08 (0.74)
	t-test	$t(280) = 4.2$ $p < .001$	$t(280) = 1.8$ $p < .05$	n.s.
Kit 5	Real life	2.73 (0.84)	3.25 (0.55)	3.16 (0.75)
(control)	Laboratory	2.30 (0.73)	3.20 (0.73)	3.04 (0.82)
	t-test	$t(283) = 4.6$ $p < .001$	n.s.	n.s.

Student interest levels range above average (> 2.5) in the groups learning with real life contexts. While highest levels are achieved in interest in the activity (the experiments) in all groups, topic-related interest levels differ most in the two groups: students in the real life group show mean values above average, while students in the laboratory group show relatively low mean scores for both kits.

Considering the perception of the collaboration process, students are positive with mean values above 3. However, slightly more positive levels of perception can be found in the groups learning with real life contexts. This difference only becomes statistically significant if the perception of collaboration of the whole unit is rated in retrospect. Students in the real life group perceive a significantly higher effectiveness of the collaboration process than the students in the control group ($t(284) = 2.9$, $p < .01$)

Student Achievement

Student achievement levels were retrieved after each session along with the interest questionnaire. In this chapter the results of the two boxes are presented and discussed. As the items of the questionnaires asked for different contents, z-standardized results are reported along with percentage.

Table 5. Descriptive results of achievement tests and comparison analysis

		Score [%]	*Score [z]*	*t-test*
Kit 3	Real life	0.54 (0.27)	0.16 (1.02)	$t(280) = 2.7$
(control)	Laboratory	0.46 (0.25)	–0.16 (0.96)	$p < .01$
Kit 5	Real life	0.63 (0.19)	0.32 (0.98)	$t(283) = 5.7$
(control)	Laboratory	0.49 (0.19)	–0.32 (0.91)	$p < .001$

As can be seen in Table 5, students in groups working with the kits in real life context task outperformed their counterparts in the other groups statistically significant in both sessions. The difference of the performance results, however, is higher in kit 5 which might be a hint that the longer students work with real life topics referring to the same conceptual basis (here: neutralisation), the higher the performance effects get.

Role of the Teacher

It was observed could be shown that students were able to work with the kits in an autonomous and independent way without further scaffolding by the teacher so that the participating teachers felt comfortable with the classroom situation. However, as the sample is constituted of high-ability students, scaffolding options should be integrated for students who are either low-achieving or not interested in working with the kits. If students have access to materials in their chemistry classroom, the learning environment could be adapted in a way that teachers only have to provide students with the respective cards in empty boxes and hand over the control of their learning process to the students. Irrespective of the success of the group work, however, a subsequent phase of revision is recommended in which student groups are given the opportunity to compare and reflect on their results.

Teacher-Proof Environment

Providing students with a context-oriented inquiry-based collaborative learning environment has shown to have a positive effect on topic-related student interest, perception of collaboration as well as performance levels. If materials are ready-to-use, they offer teachers the possibility to let students work in an engaging learning environment and at the same time gain space for monitoring the students' learning process. In light of the ongoing reform to innovate the chemistry classroom by integrating a higher degree of context-orientation, the kits can be seen as a tool to convince reform-resistant teachers to take the chance and integrate contexts into their classrooms, with little demand on their skills and motivation. In particular since the students may operate quite self/reliant. However, a limiting factor is the predefined learning setting in which students are not given the freedom to choose their preferred context or work on the problem situation of their choice. Therefore, the kits should be regarded as modules which can be flexibly inserted at certain points during the learning process. From this perspective, the authors encourage science educators and teachers to support the implementation of learning materials which can be assembled in advance.

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5. TEACHING AND LEARNING IN CONTEXT-BASED SCIENCE CLASSES

A Dialectical Sociocultural Approach

INTRODUCTION

Internationally, many secondary school students are disengaged in science, finding the content of the curriculum unrelated to their everyday lives. Despite a rapidly changing world, outdated pedagogical approaches still persist in science classrooms where the focus is on the rote learning of conceptual knowledge, the application of concepts to routine problems, the treatment of context as secondary to concepts, and the use of practical work to illustrate principles and practices (Tytler, 2007). Context-based approaches offer a new way to engage students in science through more meaningful experiences by situating the learning of canonical science in real-world scenarios. Context-based learning has been researched previously (see e.g., King, 2012 for a full review of literature) revealing that students see the science content as relevant when taught in context (Hofstein, Kesner, & Ben-Zvi, 2000); students are more interested and motivated through learning science in context (Barber, 2000; Gutwill-Wise, 2001; Parchmann et al., 2006; Ramsden, 1992, 1994, 1997) and students' understanding of science concepts compares favourably with those taught through a traditional approach (Barber, 2000; Smith & Bitner, 1993). Other research on contexts that explores a sociocultural perspective is found in the work of Van Oers (1998) and Roth (1995).

Van Oers (1998) explored two interpretations of context; "situation-as-context" and "activity as context." In the first interpretation, context is seen as a meaningful situation or a situation that makes "human sense" (p. 476). He further explains that the cognitive structures used to make sense of the context are personally constructed and may be influenced by social factors. The second interpretation, "activity-as-context" occurs when the activity is the starting point for learning and the context emerges through the interactions between the learners. He concludes that both approaches depend on some sort of surrounding, either a situation or an activity where knowledge can be socially constructed. He advocates that context "is essentially conceived in terms of a sociocultural setting" (p. 481). The definition of "context" adopted in this study is drawn from Van Oers' first interpretation where the context is the "situation" or a "real-world scenario" that makes "human sense" to the students.

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Roth's (1995) research on authentic school science reveals "contexts" as important for learning in science. He explained that students' experience of authentic science occurs when there is commonality with the work of real scientists like going into the field to collect data. One of the criteria for "authentic science" in schools is that "participants learn in context constituted in part by ill-defined problems" (p. xiii). Roth's research has explored such contexts as the environmental issues of the local creek highlighting the need for students to engage in real-world "citizen science" for improved scientific literacy (Roth & Lee, 2004). A similar definition of context is used in this chapter where contexts are set in real-world scenarios.

The definition of a context-based approach adopted in this chapter and drawn from the literature, is one in which the context or application of the canonical science to a real-world situation is central to the teaching of the science concepts (Beasley & Butler, 2002; Roth, 1995; Van Oers, 1998). The concepts that structure the context are taught when students require the knowledge to understand further the real-world application. Such an instructional framework embodies a "need-to-know" principle: the context legitimises the learning of the science concepts from the perspective of the students and thus makes their learning both intrinsically and extrinsically meaningful (Beasley & Butler, 2002; Bulte, Westbroek, de Jong, & Pilot, 2006).

Gilbert (2006) has distinguished four models of context-based teaching that provide a framework for interpreting context-based approaches. The perspective adopted in this chapter most closely relates to model 4 in which the context is primarily considered to be a "cultural environment" that guides and shapes students' practices and understanding. This may be contrasted with model 3 in which the context is a "real-world task or problem" to be solved in the classroom while learning canonical science knowledge. Since model 3 omits the engagement of students within the local community that is central to model 4, the case studies presented in this chapter align more closely with model 4.

Prior research on context-based approaches has focussed on the relevance of the science to students' real-lives, their interest and motivation while undertaking context-based courses, and student understanding compared to traditional styles of teaching. Furthermore, work by Roth (1995) and Van Oers (1998) have explored contexts from a sociocultural perspective where the social construction of knowledge is seen as central to the learning of science through contexts. However, there have not been any fine grained analyses through a dialectical sociocultural lens where students' agency and the structures that afford students the agency for learning through contexts are examined. Research that highlights the structures teachers create in learning environments that affords students the agency for connections between concepts and contexts is new. Two recent Australian studies that investigated the teaching and learning in senior chemistry (years 11–12) and middle years science (years 6–9) classes through a dialectical sociocultural framework provide exemplary evidence for the discussion. Furthermore, Bourdieu's (e.g., 1977) notion of *fields* where a particular form of culture is enacted is used to theorise how students can populate both the real-world field and classroom field simultaneously leading to the merging of canonical science knowledge with the students' everyday literacies.

A DIALECTICAL SOCIOCULTURAL THEORETICAL PERSPECTIVE ON CONTEXT-BASED LEARNING ENVIRONMENTS

The sociocultural perspective, founded in the work of Vygotsky (1978), is based on the tenet that higher cognitive skills of individuals develop through participation in socially and culturally organised activities such as collaborative talk and interaction while engaging in meaningful activities. Lave and Wenger (1991) describe this process of enculturation of individual participation into socially organised practices as becoming a full participant or a member of a community of practice. In Lave and Wenger's (1991) "community of practice" knowledge is socially constructed. Using this explanation, the teachers and students in the science learning environment could be referred to as a "community of practice" where they participate in the social construction of knowledge.

Vygotsky (1986) explored the development of scientific concepts and spontaneous concepts in children. He defined a spontaneous concept as one which can be traced to a face-to-face meeting with a concrete situation (p. 194). He found that it was only long after a child had acquired a spontaneous concept that the child could use words to explain it. Vygotsky (1986) further explained that the development of a scientific concept usually begins with its verbal definition and starts in the child's mind at the level that spontaneous concepts only reach later (p. 192). Relating this to the current study of context-based science, the scientific concepts such as the chemistry of water quality are introduced to students through activities that situate the learning in the real-world context of the pollution of the local creek. In such a way, students are afforded opportunities to merge the real-world context of the creek (the spontaneous concept) with the scientific concepts of water quality. Vygotsky argued that the development of the spontaneous concept must have reached a certain level for the child to be able to absorb a related scientific concept. By affording opportunities for students to experience the everyday concept of the health of the local creek, may enable them to link the scientific with the everyday.

The sociocultural dialectical framework is underpinned by the work of Vygotsky (1978) and the American sociologist William Sewell (1999). Sewell (1999) viewed culture as a dialectic of system and practice where the rules and symbols of a group may shape their practice but also the practice of the group is shaped by the rules and symbols of the system. Therefore, Sewell's work suggests cultural practices can be viewed through dialectical lenses. In particular, a dialectical sociocultural framework provides a way of analysing the cultural practices associated with teaching and learning within context-based learning environments. Such a framework affords the researcher opportunities to view, through the theoretical "lens," both the teacher-student and student-student interactions revealing new insights which can inform context-based science teaching practices (Roth, 1995; Sewell, 1999). For example, a year 9 science class may be organised into small groups for observations at the local creek and for learning within the group i.e., the classroom (the structure created by the school system) is in dialectic with group work (practice). However, through the group work, recorded observations may be shared with the whole class contributing to wider data collection for all and affording opportunities for learning for the whole class (i.e., the group work (practice) contributes to learning for the whole class (structure)). In such a way, dialectics can be used to understand how learning occurs in context-based classrooms. Unlike previous studies that have reported student affective outcomes such as interest and motivation (Barber, 2000; Gutwill-Wise, 2001; Parchmann et al., 2006; Ramsden, 1992, 1994, 1997) or comparisons between traditional versus context-based classrooms (Barber, 2000; Smith & Bitner, 1993), a dialectical sociocultural lens affords opportunities for the researcher to "zoom in" on the student-student and teacher-student interactions revealing how teachers teach and how students learn in context-based science classrooms.

AGENCY | STRUCTURE

Sewell's (1992) definition of a dialectical approach to understanding culture was influenced by the work of the English social philosopher, Anthony Giddens. In relation to the agency | structure dialectic, Giddens (1981) insisted that structures must be regarded as "dual". That is, structures are "both the medium and the outcome of the practices which constitute social systems" (Giddens, 1981, p. 27). Sewell (1992) elaborated on Giddens' work by explaining that structures shape people's practices but it is also people's practices that constitute (and reproduce) structures. Osterkamp (1999) defines "structure" as referring to the social arrangements, relations and practices that exert power and constraint over our lives. For example, what a teacher or student can do in the real-world field of the local creek is mediated by the physical structures they work within: such as the available safe area for students to collect water quality data at the site, or the social structure of group work compared to teacher-led lessons.

The term "agency" refers to social actions by individuals and groups that challenge, resist, oppose or "question the 'normality' of the given order and their own part in it" (Osterkamp, 1999, p. 380). Giddens (1976) explains that "knowledgeable" human agents (i.e., people who know what they are doing and how they do it) enact structures, and agents act by putting into practice their necessarily structured knowledge (Sewell, 1992). For example, the teacher (knowledgeable human agent) may organise student groups as the structure for collecting data in the context of the local creek and the students (agents) may respond by collecting relevant data that determines the health of the local creek. In such a way students are afforded opportunities for learning (to act agentially) from the structure of small groups created by the teacher. The successful interactions in the group work may lead to the teacher incorporating more lessons in the real-world field rather than teacher-led lessons in the classroom. Hence, "structures must not be conceptualized as simply placing constraints on human agency, but as enabling" (Giddens, 1976, p. 161).

Another example that demonstrates the dialectic of structure | agency is the typical science classroom that has a whiteboard at the front that is suited to teacher-led instruction and may limit the agency of the students; that is, the opportunity for them to interact in the lesson. At the same time, this structure of teacher-led instruction gives time and opportunity for the students to think more deeply on the explanation for themselves, allowing them to pose thought-over questions. By asking relevant questions, student agency influences structure by changing the structure to a teacher-student exchange rather than a teacher dominated discussion. Thus, what can be done in the classroom, and the learning environment that results, depends on the interplay of structure and agency. Simultaneously, structures make no sense apart from agency: the structure depends on the participants in a situation (the students), their past experiences and the rules that have been developed in the classroom. This means that agency and structure are mutually co-dependent concepts that can be turned into ONE concept by collating them separated by a vertical line (e.g., "|"), known as the Sheffer stroke (Roth, 2005, p. xxi). For the Australian studies reported in this chapter, the agency | structure dialectic explains the interrelationships between the agency of the students and teacher and the structures in the science classroom that are crucial for teaching and learning to occur.

Fields

The theoretical framework for the studies described in this chapter drew on social constructs explained by the French philosopher and sociologist Pierre Bourdieu (e.g., 1977). The notion of a *field* is used to theorise the practices that occurred in both a context-based senior chemistry class and a context-based middle years science class. Grenfell (2007) who interpreted the work of Bourdieu, explains that Bourdieu's notion of a field is a "structured social space based on the objective relations between those who occupy it, and hence the configuration of positions they hold" (p. 55). Grenfell (2007) further elaborates that fields can be quite heterogeneous and large such as the media or education; others could be small and local – microcosms (p. 59). In the field people behave in certain ways such that the practices of people structure the field. Originally, Bourdieu (1977) used the term "field" to represent both the physical location and the structure and resources that constitute that location. Applying this to the context-based studies, the local creek where students collect ecological data and conduct water quality experiments is considered a field (a microcosm of the local community) and the classroom where the data were analysed is another field (a microcosm of the field of education). The teacher's interactions with the students may structure the learning that occurs in both fields.

The Metaphor of Fluid Transitions

Concerning context-based education; a key issue is to assure that students can understand the scientific concepts as they are situated in the contexts. For example, rather than teaching students about the concept of pH unrelated to any real-world example, it can be embedded in the context of the health of the local creek. In such a way, students are afforded opportunities to make connections between pH and water quality. Such seamless connections between concepts and contexts may occur when students smoothly shift between concepts and contexts in their conversations and written work. The metaphor of "fluid transitions" has been used to theorise these connections as one way of determining how learning occurs in context-based education.

The term "fluid transitions" evolved from Beach's (2003) work on "collateral transitions." Beach (2003) defined transitions as "a developmental change in the relation between an individual and one or more social activities" (p. 42). He further explains that changes in their relation can occur through a change in the individual, the activity or both. Beach uses transition as a construct to understand how knowledge is generalised or propagated across social space and time. In particular, he describes collateral transitions as involving "individuals' relatively simultaneous participation in two or more historically-related activities" (p. 43). Examples of collateral transitions include students' daily movements between home and school, part-time work after school and school, language arts and science classes during their school day. These transitions are multi-directional in that students can move back and forth between these activities. The back and forth movement that Beach (2003) describes is similar to the *toing and froing* between concepts and context that may occur in the conversations and written work in a context-based science classroom. Even though the students may not physically move between the two fields, the classroom and the real-world community, their conversations and written work may move back and forth between canonical chemistry and the context. These collateral transitions may result in "development" or "transformation of knowledge" as students' transition between the two fields (p. 44).

Beach's metaphor of "transitions" could be elaborated further to the term "fluid transitions" to describe the back and forth movement between concepts and contexts that may occur when students are learning in a context-based science classroom. The term "fluid" implies there is a *toing and froing* between concepts and context. This is similar to Van Oers (1998) notion of (re)contextualization or contextualising something in a new way. For example, a student may have learnt about pH in a previous science class but is asked to now apply it to the context of water quality. In such a way, the student is transferring knowledge about the concept of pH from a previous learning context to the real-world context of the local creek. The metaphor and its application to context-based learning environments are elaborated below in the case studies.

CASE STUDIES ON TEACHING SCIENCE THROUGH A CONTEXT-BASED APPROACH

Below two cases studies will be presented illustrating the sociocultural approach. Teaching and learning are co-constructed; however, they are separated to highlight findings that contributed to each from the two Australian case studies.

Teaching

Recent ethnographic Australian studies investigated the teaching and learning that occurred in two different learning environments in context-based science classrooms in metropolitan city schools. In both cases, the real-world context that structured the unit was the school's local creek. A final culminating report that drew conclusions about the health of the local creek based on scientific evidence was a required assessment task for both studies. The first study was conducted in a year 11 chemistry class in a private boys' school and the second study was conducted in a co-educational year 9 middle years classroom in a public high school. While the two studies differed in the complexity of the science concepts required to understand the context, the similarities and differences in the pedagogical approaches adopted by both teachers provide valuable insights into how teachers interpret a context-based approach.

The context-based approach adopted by both teachers included a sequence of lessons where the real-life application or context (the health of the local creek) was central to the teaching, and content was primarily taught in response to the students' "need-to-know." Initially, a context-based model (Beasley & Butler, 2002) was used to plan the lesson sequence for the unit and to help in the design of the inquiry-based task, however, the teachers were open to following the lead of the students as the unit progressed. In particular, they were committed to an approach that gave "power back to the students" as suggested by the middle years teacher in the following quote:

> Whereas the approach for this unit is giving power back to the students and following along what they are coming up with and being flexible as to where they want to go…how they want to structure things …as being a lot more demanding of the students but they have responded a lot more positively than expected. (Interview 1, 19/5/10)

Similarly, in the chemistry class in year 11, the teacher was open to a flexible approach where student questions led the learning:

> I think this unit really lends itself to that process of student inquiry and answering questions as they come along… (Interview 5)

An analysis of the teaching that occurred in both cases revealed the context-based approach adopted by the teachers incorporated a variety of structures such as teacher-led lessons, laboratory activities and group-work that expanded their agency through an array of teaching strategies, as well as providing opportunities for student-student and teacher-student interactions. This resulted in structures that were dynamic; that is, they changed within lessons and between lessons. While a detailed analysis of the lesson sequences is provided in King (2009) and King and colleagues (2011), a general summary of the lesson types that occurred in both studies is listed below in Table 1.

Table 1. Lesson types

Lesson Type	*Explanation*
Teacher-led	Predominantly a one-way exchange of information from the teacher to students. Students demonstrate their knowledge only by answering questions posed by the teacher
Group Work	Students work in small groups
Laboratory Work	Students carry out laboratory experiments in groups
Creek Visits	Teacher and students went on an excursion to the local creek
Research	Students access necessary library/computer resources to conduct their research

To provide further insights into structures in the lessons that increased student agency, each case study is expanded separately.

Case study 1. In the chemistry class in year 11 there were 19 lessons where the students were required to conduct water quality investigations in groups on water samples collected from the local creek. The water samples were provided by the teacher with a map of the locations from which they had been collected. Throughout the first 12 lessons (Lessons 1–12: Phase 1) of the teaching sequence, the chemistry concepts or content were taught primarily in response to student questions when the need arose. The teacher encouraged student agency through structures that enabled students to ask questions, complete group work and conduct laboratory tests. However, in the second phase (Lessons 13–19: Phase 2) of the teaching sequence or the last seven lessons, the teacher changed her pedagogical approach due to perceived constraints of time to complete the planned curriculum and opportunity for students to demonstrate the level of conceptual understanding she had anticipated. Despite the teacher’s best intentions to teach content as the students’ required the information, the constraint of limited time and her perception that her students were not acquiring conceptual understanding of the stated concepts, caused a change in her pedagogical approach. In the second teaching phase she taught three teacher-led lessons featuring intermolecular forces of attraction, the solvency of water, and the structure of the water molecule unrelated to the context of the creek. Interestingly, the students did not integrate this theory into the main body of their final report like the water quality chemistry conducted in the first phase of the teaching sequence, but rather tacked it on in an appendix indicating they perceived it as separate to the context. The teacher-led coverage of content in Phase 2 diminished student agency resulting in the students being unable to connect the theory with the context of the health of the local creek. Unlike the first teaching phase, the students were not afforded the agency to interact in group work and the opportunity for student-student interactions decreased. Changing the structure in Phase 2, changed the agency of the students. Consequently, in the second phase of the chemistry unit, the context did not direct the learning.

Case Study 2. In comparison, the context-based middle years study required the students to make weekly visits to the creek where they recorded data on the ecology, environment and water quality of the creek and the nature of the surrounding flora and fauna. Unlike the chemistry study, where the students did not actually visit the local creek, the students in the middle years study were encouraged to view the creek as an important asset of the school community which needed to be protected and preserved through weekly visits. Throughout the study, the middle years students began to view the creek from multiple perspectives resulting in a better understanding of the importance of environmental management and community. The teaching sequence in the middle years classroom centralised all learning around the context where the teacher implemented structures that afforded students the agency to connect science concepts with the data collected at the creek. In this study, the teacher did not revert to teacher-led transmission of content unrelated to the context like the chemistry study. Throughout the whole unit, content was predominantly taught on a "need-to-know" basis through students' agential initiation of questions both at the creek and in the classroom.

In both studies, the teachers were committed to changing their teaching practice by adopting a pedagogical approach that centralised the context where content was taught in response to students' "need-to-know." To do this, they exercised their agency to implement structures such as group work, laboratory work and creek visits that prioritised student-student and teacher-student interactions that afforded students the agency to make connections between concepts and context. Both studies revealed the importance of teacher's agency in choosing appropriate structures for learning environments that centralised the context for context-based teaching.

The subsequent learning that occurred in the context-based classes is explained in the next section highlighting the differences in student outcomes from the two approaches.

Learning

The metaphor of fluid transitions originating in the work by Beach (2003) was used in the chemistry study to refer to the *toing and froing* between concepts and context that occurred as the students moved backwards and forwards between the canonical chemistry concepts and the context. When students demonstrated this *toing and froing*, they were making connections between the canonical science and the context. This occurred in both the student-student interactions and the written task in the chemistry study (see King, 2009 for a full explanation of written work).

For case study one, data were collected over a full term's work (11 weeks) from 19 chemistry lessons and included classroom documents, students journals, interviews with students and the teacher, and video and audio recordings of teacher and students. The analysis involved the transcription of all recorded lessons, interviews and in-class interactions. Themes were distilled from the initial review of relevant literature, as well as content analysis of project work. The analysis focussed on two selected groups of students who were representative of the full range of academic and cultural diversity in the class. The students' written and oral work was categorised into three standards (see King, 2009 for full details) and then the data were searched for instances and non-instances when the students used the discourse of science to explain the water pollution of the local creek. In other words, the author searched for instances where the chemistry was used in a canonically accurate form to explain the test results through comparison to standards. For example, below is an example of a fluid transition:

> Sample 1 had an average of 14252.4/100ml for a Faecal Coliform reading. This is a very high level of Faecal Coliforms and should be treated immediately. No recreational use should occur here whatsoever. (Written Report)

In this example, the student had accurately recorded the Faecal Coliform results and compared them to the Queensland Water Quality Guidelines (Queensland Government Environmental Protection Agency, 2006). Following this, the suggestion that the water should not be used for recreational use is an accurate connection to the context. In case study one, the students did not physically go to the creek so the water quality analysis was applied to the areas from which the samples were collected via maps. Students were making sense of their results by *toing and froing* between their water quality data and the map of Yabbie Creek. The faecal coliform results (concept) were accurately interpreted and applied to the recreational use of the creek (context) demonstrating a fluid transition.

Fluid transitions occurred in group conversations. The following excerpt is representative of the conversations that occurred in group activities while the students compared their water quality test results with water quality standards from the Queensland Water Quality Guidelines (Queensland Government Environmental Protection Agency, 2006). Students had access to a map of Yabbie Creek while they were working in small groups:

01. Mark: pH is alkaline

02. Shane: Where did we get pH?

03. Mark: 8.3 which is polluted and alkaline *(referring to the acceptable pH levels in the table depicting typically clean and polluted values for fresh water of 6.5–7.5)*

04. Shane: What's healthy?

05. Mark: 6.5 to 7.5

06. Shane: 6.5 to 7.5 is that ppm or mg/L?

07. Mark: It's a measure *(in other words there are no units for pH)*

08. Shane: Oh and what was the result?

09. Aaron: 8.3 on average which is polluted

10. Mark: Ah the turbidity… we are looking pretty dodgy with this actually I don't trust those results

11. Aaron: What's the average then? *(referring to turbidity)*

12. Shane: It's 25 pretty much everything's polluted *(referring to turbidity reading)*

13. Mark: What did we say it was? We had a result for turbidity *(looks up table)* less than 3 NTUs*. (refers to table for acceptable range which is less than 3 NTUs and more than 20 is considered very polluted)*

14. Shane: And if it's 25 it's so the Sample 1 is 25 NTUs

15. Mark: So the turbidity is?

16. Aaron: NTUs what's NTUs?

17. Mark: Nepholometric Turbidity Units…very polluted so it's very very Polluted *(referring to the map of the creek)* (MP3 recording)

The students were making fluid transitions between the water test results and the water quality of Yabbie Creek (the local creek) as they applied the experimentally determined pH and turbidity values to conclude that Yabbie Creek was not within the acceptable range. This excerpt was typical of the exchanges between the students where the structure of group work afforded them the agency to demonstrate fluid transitions between concepts (pH and turbidity in this case) and context (Yabbie Creek) through student-student interactions. Through the social interaction of group work, students were provided information that became a resource for the written task. Such fluid transitions were evidence of student learning in the context-based chemistry class. This unit was taught early in the students' first year of chemistry so concepts were still developing; hence the chemistry concepts in Phase 1 were associated with water quality parameters. Nevertheless, the analysis of results and application to the context of the creek introduced students to the higher-order thinking necessary for success in chemistry.

In case study two, the data were collected during one three-month term (11 weeks) in a ninth grade science class that was situated on Spring Creek. Data included field notes, student journals, and interviews with students and teacher, and audio and flip cam recordings created by students when at the creek (see King, 2011 for a full summary). All salient recordings were transcribed and themes evolved from the analysis. In particular, the data were searched for instances when the students merged canonical science with the context.

The middle years study (case study 2) required the students to make weekly field visits to the local creek where they actively sought information about the creek environment through investigations in small groups. Their conversations at the creek demonstrated more than just a *toing and froing* between concepts and context but rather an interconnection between the environmental science they were exploring and the context of the local creek. These conversations were evident in the student-student conversations in small groups and the teacher-student conversations that occurred at the creek. In particular, when the teacher or researcher probed or challenged students' understanding there was evidence of the merging of the canonical science with the context. One representative example that occurred at the first creek visit demonstrates students' merging of science knowledge with the real-world when they were probed by the researcher (who also assisted with teaching when required) about the habitats of the animals they were observing:

01. Laura: Must be like sort of a lot of fish in here.

02. Beckie: Must be a good habitat for like the animals.

03. Laura: And we could say there must be fish here because I think ducks eat fish.

04. Researcher: So, why do you think it's a good habitat for the animals?

05. Beckie: There's heaps of like vegetation around there which would be good. It's not murky and not polluted.

06. Laura: And the temperature is right.

07. Researcher: Plus you've also found evidence of all these aquatic life and non- aquatic life …

08. Beckie: Yeah, and like the water is not like freezing or anything.

09: Researcher: So, it's got the right conditions for them to live in.

10. Laura: Except there is some litter and stuff but it's clean (Flip Cam recording, 16/4/10).

The students were "in the moment" as they observed the animals and discussed the habitat they could see at the creek that was suitable for their survival. The science concept of habitat and conditions necessary for animal survival, were discussed as students made real-world observations. By immersing students in the real-world context on a weekly basis, no longer were they transferring the concepts to an “imagined” real-world like the chemistry study, rather they were speaking and writing about the context that surrounded them. In other words, the context became the students’ lived experience. The learning environment of the local creek gave students a purpose for their research and afforded them opportunities to talk and write about what they observed by interconnecting the science concepts with the context.

FIELDS IN CONTEXT-BASED SCIENCE

In the chemistry study even though students did not appreciate fully that the creek was situated in the broader context/field of the local community, their classroom conversations showed evidence of *toing and froing* between two fields. Through structures such as group work and the opportunity to write, students were afforded the agency for fluid transitions between the classroom field and the real-world field of the local creek.

In comparison, in the middle years study, the field of the classroom where more formal learning occurs, and the field of the real-world creek merged when students made weekly visits to the creek. No longer were science concepts applied to a “hypothetical” real-world for sense-making to occur in a *toing and froing* manner as demonstrated in the chemistry class, but rather the students’ conversations at the creek demonstrated a merging of the canonical science and the real-world context. The real-world environmental science they observed and recorded at the creek and the IT resources such as flip cams they used to collect their data became the same resources they used in the classroom field to draw conclusions about the health of the creek. Also, the students’ conversations in class frequently referred to the creek they had visited each week in such a way that the two fields had merged – the classroom and the creek. In the middle years study, the teacher employed a pedagogical approach that encouraged the diffusion through the porous boundaries of two fields, the real-world field and classroom field, resulting in the merging of students’ everyday literacies with the canonical science. By immersing students fully in the real-world field, the *toing and froing* or fluid transitions were replaced with a blending of the canonical science and the real-world context where the distinction between the two was indefinite (Barton et al., 2007).

CONCLUSION

In the first case study, the chemistry was taught on a “need-to-know” basis for the majority of the unit but was limited to an “academic” classroom structure where students did not visit the real-world field. The interchange between teachers and students varied depending on the structures created by the teacher that included group work, laboratory work and teacher-led lessons. In this phase of the teaching sequence, students exhibited fluid transitions between the concepts and the "theoretical real-world" constituted by the context: the water quality of the local creek. For the second phase of the teaching sequence where the context did not drive the teaching, students did not make fluid transitions demonstrated by the addition of the theory of water chemistry, unrelated to the context, in an appendix at the end of the report.

In the second case study, all of the content was addressed through a "need-to-know" approach and students' agency was not limited to a classroom structure. The structure of group work in the real-world field afforded students the agency for merging canonical science with the context (the health of Yabbie Creek) in their conversations.

This chapter highlights the importance for teachers to expand their agency and create structures in context-based approaches that are not confined to the "academic classroom". Such learning environments may afford students the agency for establishing personally relevant knowledge either through fluid transitions or the merging of the canonical science with their real (out-of-school) lifeworlds.

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SECTION II

TEACHERS CREATING CONTEXT-BASED LEARNING ENVIRONMENTS

DAVID-S. DI FUCCIA AND BERND RALLE

6. TEACHERS IN LEARNING COMMUNITIES

An Insight into the Work of the Project Chemie im Kontext

INTRODUCTION

From 2002 to 2007, more than 30 teams of German teachers worked cooperatively on the implementation of *Chemie im Kontext*. At regular meetings, the teachers planned teaching series, created immediately applicable teaching material, and discussed current developments concerning educational policy. This chapter covers the framework conditions of the working process of an exemplary learning community, including the expectations of the participating teachers, the problems which occurred during their cooperation, as well as the solutions the team has found. Thus, this contribution gives an insight into the precise working process of such a local learning community according to *Chemie im Kontext*. Finally, it will be shown how this project led to a new project of teacher professionalization by giving an insight into a concrete research project, which directly arose from the teachers' experiences with (teaching) *Chemie im Kontext*.

FRAMEWORK CONDITIONS OF *CHEMIE IM KONTEXT*

The learning community, this article will focus on, consisted of twelve teachers from six schools in Bavaria and was embedded in the project *"Implementation of innovative teaching concepts using the example of Chemie im Kontext"*. This project was sponsored by the Federal Ministry of Education and Research as well as by fourteen involved federal states. It was conducted by the IPN of Kiel and the universities of Dortmund, Oldenburg and Wuppertal (Parchmann et al., 2006; Nentwig et al., 2007; Demuth et al., 2008).

In order to implement the idea of *Chemie im Kontext* in schools, a symbiotic strategy was chosen. This strategy combines successful elements of the top-down- and bottom-up-approaches used so far (Fey et al., 2004; Eilks, Gräsel, & Ralle, 2004). For this purpose, the schools, the universities and the educational administration were actively involved. Hence, a wide-ranging guidance and support by the universities had been ensured. A precondition for participating in the project was that at least two teachers from every school took part (the so-called 'tandem model'), so that they could support each other in implementing the new learning environments in their everyday teaching.

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In order to provide the space for individual initiative as well as creativity, the work of the local learning communities should not be regulated more than necessary. Therefore, *Chemie im Kontext* did not and still does not offer the participating teachers a universal conception for an entire chemistry lesson. Rather, *Chemie im Kontext* provides a selection of model teaching units and a theoretical framework within which the teachers are free to create their own units or adapt existing ones to the principles of *Chemie im Kontext* and/or their local necessities.

In this way, the teachers' learning communities have developed lessons following the concept of *Chemie im Kontext* and also evaluated the underlying conception.

THE CONCEPT OF *CHEMIE IM KONTEXT*

The principles of *Chemie im Kontext* as well as the related implications for teaching have been thoroughly discussed at the beginning of the working process in the learning communities.

Following constructivistic approaches to learning (Bodner, 1986), teaching according to *Chemie im Kontext* is based on three pillars (see Figure 1): orientation towards context, connection to basic concepts and methodology (see e.g. Nentwig et al., 2007, Demuth et al., 2008).

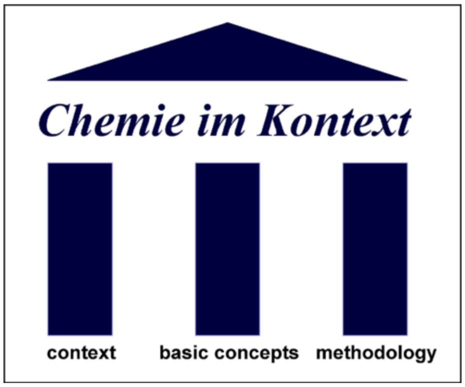

Figure 1. The three foundations of Chemie im Kontext

The Orientation towards context aims at finding chemical topics which are complex, relevant and meaningful to the students. Furthermore, the topics should emphasize the relevance of chemistry for their own lives or society. Often these contexts are based on students' living environments. Such contexts should go beyond mere motivation and rather become a driving element in the planning and structuring of the whole teaching unit. It is necessary that the students are presented with such a context, so that diverse questions and interests will be raised. In the following chemistry lessons, the students' questions can be answered with the help of chemistry.

The second pillar, the connection to basic concepts, assures that the knowledge students have gained within contextualised lessons is detached from the context in which they have acquired it. In this way, it will be on hand when being necessary in another situation or dealing with a different issue. In addition, the connection to basic concepts (such as donator-acceptor-concept or the connection between structure and property) is to assure that students can structure their knowledge even if it is not gained in the sequence recommended by the traditional curricula. Thus, building up a systematic structure of concepts in the field of chemistry is a significant and emancipated aim within the framework of *Chemie im Kontext*.

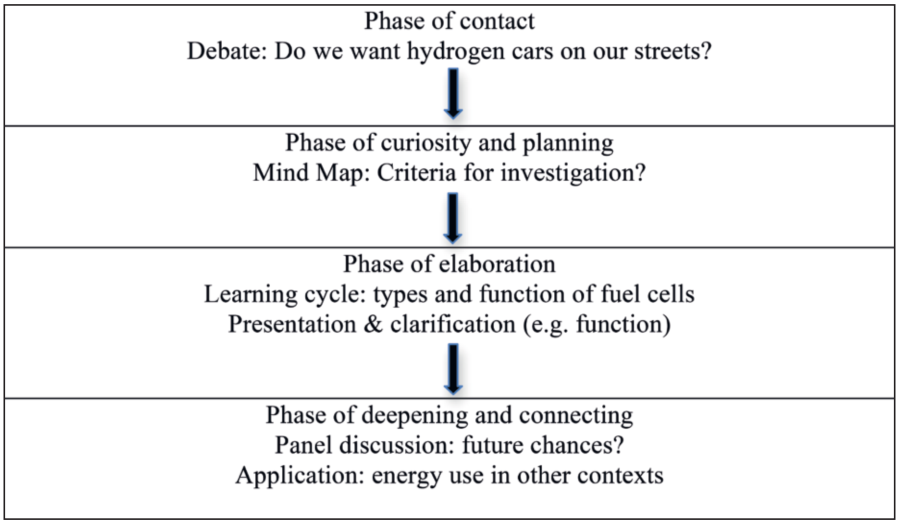

Figure 2. The four phases of Chemie im Kontext *units, Example-unit: Hydrogen – fuel of tomorrow?*

The aim to develop basic concepts of chemistry by following students' questions to a complex context demands an appropriate use of different methods. Consequently, a variety of teaching methods are the central element of the pillar "methodology" of the concept *Chemie im Kontext*.

To implement the ideas of context-orientation, the opportunity for students to ask their own questions, the use of different methods and the decontextualisation and connection to basic concepts, a unit following *Chemie im Kontext* usually consists of four phases (Figure 2). During the contact phase, students are confronted with the context. The aim of using diverse materials and media is to illustrate the significance of the context for the students and/or society.

The following phase of curiosity and planning is supposed to collect and structure questions that arose in phase one in such a way that they can be addressed and answered appropriately within the subsequent phase of elaboration. This phase aims at dealing with the students' questions in a way that the necessary chemical expertise is facilitated. This should be done in a way, that students recognise the connection to the context and their own questions at any time and perceive chemistry as helpful and meaningful for them.

Within the last phase of deepening and connecting, interrelations to previously discussed contexts take place. Furthermore, this phase aims at cumulatively establishing chemical basic conceptions (Demuth, Parchmann, & Ralle, 2005).

TIMEFRAME

The Bavarian learning community consisted of a total of twelve teachers coming from six different schools. One of these teachers served as a coordinator, staying in touch with the educational administration in order to answer organisational questions such as the reimbursement of travel costs or exemptions, moderating and organizing meetings of the learning community. Apart from structuring the designed material, the coordinator has also been the contact person for all questions regarding school implementation. Additionally, the work of the learning community has been accompanied by an advisor from the involved universities. The advisor established a connection to the project management, made didactical and methodological suggestions, assisted in the planning of teaching units following *Chemie im Kontext*, and gave the group members an outsider's view without trying to overrule the group decisions. The results presented in this article are based on the structured observations of the advisor of the Bavarian group of teachers, who fixed his observations and double-checked them with videotaped material and results of an accompanying questionnaire-study.

After the initial meeting the learning communities have met at one of the participating schools on average every two months for six hours. The work of these learning communities basically followed the subsequent cycle of successive optimisation (Figure 3), as for example the model of participatory action research

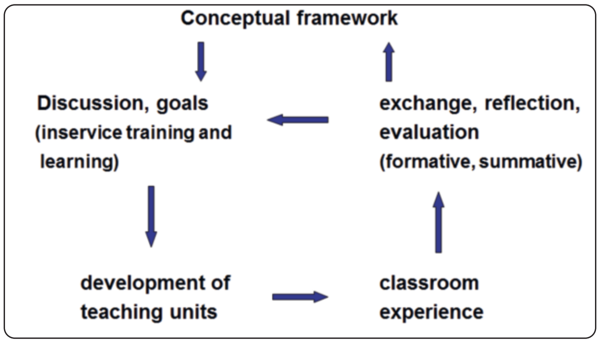

Figure 3. Activities in the learning community

suggests (Eilks & Ralle, 2002). The cycle of implementation and optimization within this framework starts with creating a teaching unit according to *Chemie im Kontext* or with the adaption of an existing unit to the corresponding conditions of the schools. This unit has been conducted by every participating teacher. After its implementation, the teachers met again to analyse and optimize the unit, which then was retested one year later. The knowledge gained from planning a unit cooperatively and from exchanging the experiences after conducting the unit, then has been taken into consideration for the next unit. Moreover, it has also been monitored whether the changes made on the basis of the experiences from conducting the last unit showed the desired results (Di Fuccia et al., 2007).

In doing so, the Bavarian learning community has planned and implemented five teaching units during the first three years of their work, of which the first two units were adaptations of existing units from other regions of Germany, while the last three units were completely designed by the Bavarian teachers. As the work ended on average 1.5 units had been designed and tested every year:

7. *The food taster* (elementary instruction chemistry, grade 9)
8. *Desired burns – unwelcome consequences* (grade 9)
9. *Only water!?!* (grade 10)
10. *All about lime* (grade 10)
11. *Bread made of air* (grade 11)

One year after having been started with the first learning community a subsidiary community could be established so that the efforts to implement *Chemie im Kontext* accelerated. Following the basic idea of a symbiotic implementation strategy, a teacher who already worked in the initial group and therefore has been able to contribute important experiences has moderated this new learning community. The university advisor has been at hand, too, but his attendance has not been as close as in the first learning community in order to promote a self-sustaining way of spreading *Chemie im Kontext*. The working of the subsidiary will not be considered in this article.

TEACHERS' AIMS AND EXPECTATIONS

At the beginning of the working process of this learning community of Bavarian teachers the participants were asked about their expectations concerning the implementation of *Chemie im Kontext* by using a self-constructed questionnaire (Figure 4, left bars).

Before teaching according to *Chemie im Kontext*, teachers expressed particular concerns about the practicability of such teaching units in everyday chemistry classes. Another concern was that it might be difficult to cover enough content knowledge by using such units because the phases of contact and curiosity are very time-extensive. The time invested in these two phases, in turn, is not available for teaching the chemical content knowledge. On the other hand, they were convinced

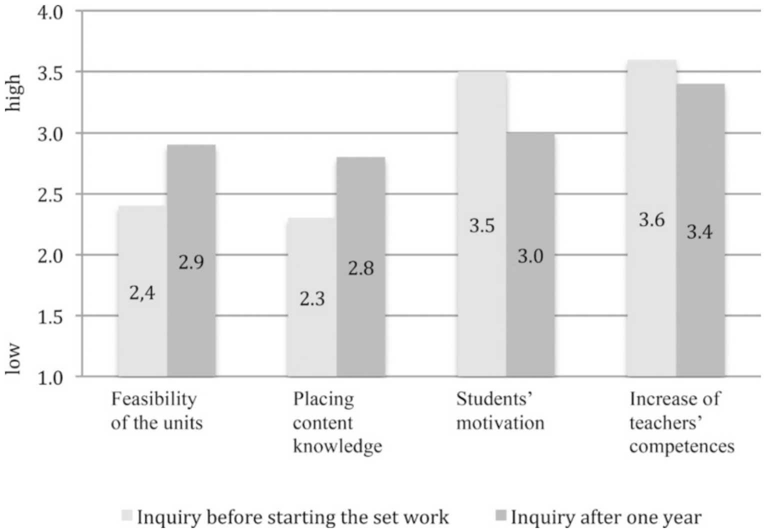

Figure 4. Teachers' expectations and perceptions

that using units following *Chemie im Kontext* would have positive effects on students' motivation and on their own teaching competences. As the results after having planned and used four *Chemie im Kontext* units show, teachers were not concerned about the possibilities to teach content knowledge or to use such units in everyday teaching any longer, while on the other hand they lowered their rating of how much those units will motivate students.

TEACHERS CREATING CONTEXT-BASED LEARNING ENVIRONMENTS: CRUCIAL POINTS AND SOLUTIONS DURING THE PROGRESS

The Balance between the New and the Traditional

Especially at the start of the work, the point in question was whether a unit following *Chemie im Kontext* involves a totally new design of the whole lessons, or if one could integrate more of what was usually done into this new conception as was considered at first glance. With the expressed concerns regarding practicability and transfer of professional knowledge in mind, the learning community decided to focus on the implementation of the first pillar for a unit following *Chemie im Kontext* mentioned above-the orientation on context. Consequently, the phase of contact became the particular topic of cooperative development and planning while the teachers decided to use as much existing material as possible for the subsequent lessons to ensure the practicability and transfer of professional knowledge. The learning community did not – in this phase – start adding additional innovations such as the diversity of methods and the consideration of students' questions when planning the phase of elaboration at first. The university adviser took the concerns of the teachers seriously and did not insist or exert any pressure in order not to lose the teachers by asking too much of them.

In the course of the project, the wish for additional and further reaching changes then arose from the teachers themselves based on the experiences with the units planned and conducted. For example, It became clear that an effective way of dealing with a context automatically leads to the occurrence of students' questions. This not only suggests a certain co-responsibility of the students in the design of further lessons but makes clear that student voice and agency is actually needed. And finally the experiences with conducting the first context units showed the teachers, that a variety of teaching methods is a suitable answer to the many facets of contexts and corresponding questions of the students. Thus, after beginning with focussing on the phase of contact other innovative steps followed naturally.

On the one hand, this way of driving the innovation by experiences with incompletely renewed units increased the acceptance of further innovative steps. On the other hand, it showed that the additional pillars of *Chemie im Kontext* are not only further claims but basic conditions which consequently derive from orientation towards context.

THE LENGTH OF THE CONTEXT UNIT

As the contexts are close to students' everyday lives and address complex topics, they often include diverse technical aspects. On the one hand, this is welcomed and a key element in teaching according to *Chemie im Kontext*. On the other hand, one has to keep in mind that the students' motivation decreases when compelled to focus on one single context for a longer time. Exactly this happened with the first context of the Bavarian teacher team, 'The food taster'. This is most obvious in the following statement of a pupil: "Will we deal with coke today again?" For this reason the learning community decided to test different lengths of teaching units and reduced it gradually so that a productive unit of minimum length was reached. From this, one can conclude – not only for the Bavarian circumstances – that a length of seven to ten lessons is optimal in order to maintain students' motivation and to meet the requirements of the contexts simultaneously.

"How do I Find the Appropriate Context"

In the concept of *Chemie im Kontext*, the selection of a suitable context is of particular importance since it affects significantly the students' motivation and their willingness to participate meaningfully and effective in class by asking questions etc. The context has to be relevant to the students and its introduction should be followed with a phase of contact allowing the students to ask some questions. On the other hand, the context should not raise too many questions to answer. Questions remaining unanswered in the course of the teaching unit will affect the students' motivation negatively. And finally the context has to offer opportunities to address the mandatory teaching content as required by the curriculum (need-to-know principle).

Considering the concerns of the Bavarian teachers about the remaining room for transferring chemical content knowledge and meeting the demands of the Bavarian centralised final exams, the contexts were mainly chosen to be closely connected to the curriculum. The very first context, however, had been an exception because it was originally designed by experienced teachers of another federal state of Germany and thus did not completely match the Bavarian circumstances. It covered a large section of the mandatory content in the Bavarian curriculum, but in a way very different from the usual one and posed high requirements regarding the use of different teaching methods.

As an approach to teaching, *Chemie im Kontext* may have been too challenging-both for students and the participating teachers. Participants were not very satisfied with this first context although optimizing the unit based on the experiences of the first run could reduce some weaknesses. After this instructive experience with the first unit, the following contexts were limited to narrower sections of the curriculum. Here, experiences were generally good and the teachers step by step developed a wish to broaden the contexts' scope and cover a larger section of the curriculum, as was initially intended by the developers. Following this 'starting-gently strategy', the next topics again expanded a little. It was interesting to observe that these expansions, now emerging from the midst of the learning community, obtained more approval from the teachers and the students than when imposed during the first attempt.

Preparatory Effort

The first context, in addition to being the first experience for the teachers with a unit following *Chemie im Kontext*, included a huge number of experiments to be conducted by students. This required a great deal of preparation for the teachers, if not to characterise it as above-average. That is why the next context was chosen in such a way that it required less extensive preparation. On the one hand, this succeeded because the amount of experiments conducted by students was reduced. On the other hand, more time was needed due to a more open design of the units which allowed better possibilities to react to necessary spatial or temporal adjustments.

The teachers involved also reported that the tandem model, that formed the basis for participation, offered them some relief in their preparatory effort because the teachers of one school were able to prepare their lessons cooperatively – which is not usual in German schools.

These synergy effects account for the decrease of preparation time so that after the first year, when the learning communities reported back, this point was no longer of concern.

ASSESSMENT IN LESSONS ACCORDING TO *CHEMIE IM KONTEXT*

At the beginning, the Bavarian teachers as well as the advisor tried to estimate whether assessment in units following *Chemie im Kontext* could be problematic and whether there would be an immediate need for new assessment instruments. This did not seem to be the case and after having conducted the first units it was clear that a usual assessment as in conventional settings was possible. But as the teachers got more and more used to teach according to *Chemie im Kontext*, it turned out that the conventional assessment tools were not able to address all the different abilities required from the students in such settings. That is why the teachers developed interest in additional diagnostic instruments and used every opportunity to elaborate on diagnostic tools with the advisor. As a result, the teachers involved enlisted for a project that used concept maps for assessment purposes during group work and also participated in a research work that dealt with assessing students' experimental work (see below).

Dissemination of Chemie im Kontext

The dissemination of the concept *Chemie im Kontext* was a main concern of this implementation project. Although the school administration's support in all involved schools was exceptional, a spreading of *Chemie im Kontext* in the participating Bavarian schools appeared to be problematic. Indeed, often the two teachers taking part in *Chemie im Kontext* were the only ones in the teaching staff of their schools who were interested in this innovation. Furthermore, it seems that the colleagues who did not participate in this project frequently just saw the efforts the participating teachers put into the implementation but failed to see the benefits arising from the cooperation of the two teachers and from the professional exchange during the meetings of the learning community, so that their willingness to participate decreased steadily.

Although the dissemination of *Chemie im Kontext* turned out to be quite problematic within the participating schools, the inclusion of schools not involved in the learning communities so far had been more successful. Among others, the Bavarian Academy for Teacher Training and Personnel Management showed great interest in the project. Special teacher training courses were set up there where the members of the Bavarian learning communities reported their experiences with *Chemie im Kontext* and were available as tutors.

AN EXAMPLE OF TEACHERS CREATING THEIR OWN RESEARCH INTEREST: LAB WORK AS A TOOL FOR DIAGNOSIS AND ASSESSMENT

Teachers' collaboration as described above led to a remarkable broadening of the scope of interests and topics covered in the learning community. Beginning with teachers sharing their experiences and learning that others struggle with some of the deficiencies or problems they had themselves, they started to identify shared problems in which they longed for further professional development. One of these problems was that their way of teaching chemistry had changed during the implementation of *Chemie im Kontext* but that their ways of assessing and diagnosing remained the same. Teachers felt that this was inappropriate and asked for assistance in exploring new methods and tools. This particularly concerned lab work which often stays "un-assessed" in German chemistry lessons.

Following the initiative of the teachers, a new group, consisting of teachers involved in *Chemie im Kontext* in Bavaria and teachers from Saxonia and Northrhine-Westfalia, was established and supervised by the adviser of the Bavarian group of teachers. This group worked in a setting similar to the one that was used for implementing *Chemie im Kontext*.

Research Questions

Teachers participating in the project also collaborated with the advisor in his research on the following research questions, which arose from the prior work of the learning community, in a participatory action research design (Di Fuccia & Ralle, 2006):

1. How can lab activities be used as an assessment instrument, which considers broader fields of competence?
2. Are there any further effects using lab activities for assessment purposes? Are there any further ways to use lab activities for assessment purposes?

The participatory action research described above was complemented by a pre/post-questionnaire study conducted by the scientific advisor asking for reasons in favour and against an assessment by lab work as well as for changes in the teachers' and students' attitudes and behaviour towards lab work. Finally, some of the teachers involved were interviewed. The results of this complementing study were used to validate the experiences reported by the teachers. Every instrument developed by the researchers was tested in school and optimized in light of the experiences gained in the project over the course of three years.

Material Developed in the Learning Community of Teachers

In cooperation with the adviser, teachers developed, tested and optimized different tools, which can be used to diagnose or assess students' understanding when doing lab work. For instance, these tools comprised observation- and introspection-sheets, modified or incomplete experimental instructions, and instructions with blanks or different ways of asking students for a prediction before conducting an experiment and to comment on their predictions afterwards. A detailed description of the material developed can be found in Di Fuccia (2007) and Di Fuccia and Ralle (2010).

Selected Results

In the context of this article two aspects of results are highlighted: First, those related to the materials created and second, results which give an insight into how the group of teachers collaborated and which effects were observable.

As to the first aspect, the material created, it can be stated that by now there is a considerable body of experience with the ways in which tools for diagnosing and assessing students' performance in the lab can be developed and used. It could be shown that the way the experimental instructions were changed or the introspection sheets were arranged was adequate to learn more about the students' understanding. The development- and optimization-work led to a "tool box" which helps other teachers to rearrange their existing material in a way that it can be used as an assessment- or diagnosing-tool. This tool-box has already been presented in a lot of teacher training courses. The data about the effects of the use of such tools show that teachers and students often focus on very different aspects of lab work and that the use the tools can help to bring these perspectives closer together. In addition, students appreciated that teachers get a lot of information from using such tools, but they also stated that they themselves did not benefit from the use of such instruments directly and that their teachers did not sufficiently communicate about their conclusions. The results of the interview study suggest that the teachers did not talk about the results of the diagnosis or the assessment because they felt too unsure about the use of the instruments. They asked for more time to get used to the instruments before talking about the results with their students.

The second aspect to consider is the way in which the teachers collaborated. Here, it should be pointed out that it is most important to strike an agreement right at the beginning of the collaboration about the participants' expectation and objectives. Two meetings of more than three hours were needed to ensure that everyone agreed on the aims of the research project. Apart from that, this phase had the effect that the teachers become acquainted with each other, which makes it much easier for them to share their experiences and concerns. Afterwards, the collaboration turned out to be quite easy and smooth, as everyone appreciated the professionalism of the others. Remarks, criticism and hints were expressed in a helpful way.

POSSIBLE DEDUCTIONS FOR SIMILAR PROJECTS

The most important deduction, which might appear trivial at first, is that sufficient time is a requirement for any successful work in a learning community – let it be an implementation or any research work. This is valid in two different ways. First, sufficient time is needed for the actual meetings in order to allow an intensive exchange of experiences, in-depth reflection, and planning of teaching units or the development of material. For this purpose the teaching communities discussed here had at least five hours available every two months. Secondly, the project duration has to be adequate in length to accomplish the desired changes symbiotically and ultimately genetically. The case presented shows that all changes were universally accepted, which were results of the teachers' experiences with using firstly only slightly changed teaching units.

Another important result is that there never was a direct adoption of teaching materials that were prepared by the project team or in other federal states. The material was valued as an inspiration, but the teachers always created their own lessons, usually including suggestions made by the advisors or the project team.

From the learning community's point of view, to work in timely constant groups over a longer period of time seems especially beneficial for the implementation. By this it becomes possible to establish connections to colleagues from other schools. The tandem principle and the availability of an advisor also offer a network of contact persons you can rely on. At school there is the second tandem partner to collaborate with. In the learning community there is help with further questions on implementing the jointly designed teaching unit and there is an opportunity to make or receive suggestions. Last but not least, the advisor represents the immediate connection to the designers of the teaching material and owners of the concept behind it which provides an excellent channel for additional information. In their cooperation the participating teachers got to know each other better and appreciate each other increasingly. The exceptionally positive group dynamics allowed all participants to rely on the experiences and suggestions of their fellow members.

As far as the research-part of the community-process is concerned it is concluded that the commitment of the teachers has been very high because they were working on their own research questions. In addition, the teachers learnt from the implementation-part of the project that it is not helpful to create the "best material" from the 'desk-top', since this will not be adopted/implemented without changes. Rather, it is advisable to describe in a detailed way how teachers can change their own material.

SUMMARY AND OUTLOOK

In conclusion, an emphasis should be put on the way the learning community gave form to the implementation of the teaching concept *Chemie im Kontext*: they focused on essential and evident innovations – the contextualisation of lessons. Other vital new elements in the concept *Chemie im Kontext* were rejected during the planning phase. Teachers' explicit worries (namely practicability and covering enough subject content needed for the exam) led to a minimalized starting version of context-based education. But this provoked questions being raised during and after education. From their experience, teachers took the initiative to request wider contexts, a more diverse use of methods, and a strong emphasis on competence oriented contexts. They also wanted assistance in their efforts in answering research questions arising from their experiences. They advocated the dissemination and publication of both *Chemie im Kontext* and the process and results of their work.

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7. MEASURING CONTEXT-BASED LEARNING ENVIRONMENTS IN DUTCH SCIENCE CLASSROOMS

INTRODUCTION

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

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

The committee for the new science subject advanced science, mathematics and technology (ASMaT, in Dutch NLT)) also advocates the context-based approach in the curriculum (Steering Committee NLT, 2008). The committees instigated the design of test-materials to try out a new context-based curriculum. Teachers will need to adopt a context-based teaching approach to make the innovation a success. When teachers do not adopt the innovation it will fail (Fullan, 1994). However, the context-based approach is not *new* to Dutch high school educational materials. The approach and materials have been elaborated on for different year levels in the seventies for chemistry, mathematics and physics (Hooymayers, 1986; Broersma, 1987; Hondebrink, 1987). Implementing the context-based innovation in the science subjects could therefore be less of a challenge than would generally be expected (Fullan, 1994). The use of contexts has been incorporated in the state exam questions for the science subjects since the eighties and, in a far lesser extent, science textbooks

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have incorporated applications of scientific concepts in each chapter (either as a final paragraph, or throughout the paragraphs were applicable). Hence the context-based approach -in a basic form- is likely to be present in Dutch science classrooms and known to science teachers.

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

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

CONTEXT-BASED LEARNING ENVIRONMENT AND BEHAVIOUR

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

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

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

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

The second dimension concerns social interactions, i.e. that the knowledge construction occurs in exchange with other people. This process can be influenced to establish the co-construction of knowledge, where students among themselves or in talks with their teachers establish a knowledge base.

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

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

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

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

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

The combination of all four, where students collaborate in constructing knowledge from rich science contexts while being responsible for their own learning, requires teachers to adapt their teaching approach; reframing it in an coherent system. For context-based education this has been defined by using the emphasis definition suggested by Roberts (1982):

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

Van Berkel (2005) and Van Driel, Bulte, and Verloop (2008) contracted Roberts’ original seven emphases to three for chemistry. From this, de Putter-Smits, Taconis, Jochems, and Van Driel (2011) developed the concept of ’science curriculum emphases’ that comprises three definitions:

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

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

So far, three context-based learning environment characteristics have been described (context and transfer, regulation, and emphasis). In a previous study we identified five characteristics (De Putter-Smits, Taconis, & Jochems, 2013). However, for this study we use the characteristics most visible in classrooms, to be able to obtain also a student perception of the learning environment a teacher is able to create. A context-based learning environment therefore is an approach with a constructivist view on learning that supports students’ responsibility for their own learning, that uses the context as a vehicle for establishing concepts, and that has a teaching emphasis appropriate to the use of contexts, abbreviated to the three CBLES characteristics (Figure 1). Since we are interested in the classroom realisation by the teacher of these characteristics we narrow our view to teacher behaviour, both from the teachers’ as their students’ perceptions.

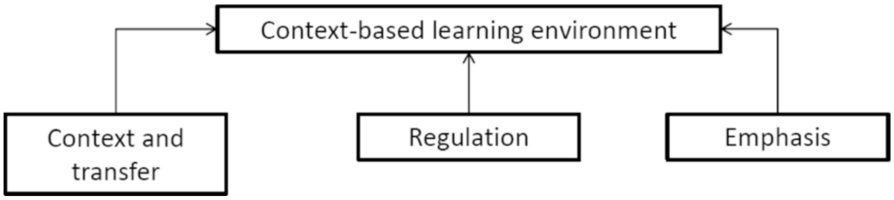

Figure 1. Model used for context-based learning environments

Research Questions

The research questions addressed in this study are:

1. How can we measure the three characteristics of a context-based learning environment as presented above in a reliable and valid manner?
   And if we can:
2. What are the differences in context-based learning environment in Dutch senior high schools between the different science subjects?
3. What are the differences in context-based learning environment in Dutch senior high schools among specific groups of teachers, such as:
   - teachers with context-based or other study material design experience compared to teachers without this experience;
   - teachers who use context-based materials in class compared to teachers who do not;

MEASUREMENT OF CONTEXT-BASED SCIENCE LEARNING ENVIRONMENTS

In search of established instruments we could use to measure the typical characteristics of the CBLES in science classrooms, we made use of the parallels of CBLES and constructivist learning environments. To measure constructivist learning environments Taylor, Fraser, and Fisher (1993, 1997) have constructed the ‘constructivist learning environment survey’ (CLES). The CLES originally consisted of 30 items divided into five scales: personal relevance, uncertainty, critical voice, shared control, and student negotiation. The CLES was shortened and re-evaluated by Johnson and McClure (2004).[1] The CLES has been widely used and reported on. The successful use in science classes is reported by Aldridge, Fraser, Taylor, and Chen (2000), Roth and Bowen (1995), and Lucas and Roth (1996). Not all scales in the CLES are relevant to a context-based science learning environment. From the scale definitions (scale definitions for CBLES’ are presented in Table 1) we select the *personal relevance* scale as an indicator for the use of contexts (close to the horizon of the learner) in the classroom. A typical item in this scale is: “New learning relates to experiences or questions about the world inside and outside of school”

(Johnson & McClure, 2004, p. 77). All items in this scale relate to the connection between the outside world and the learning of scientific ideas. We believe that the *uncertainty* scale of the revised CLES is an indicator for a KDS emphasis. This scale establishes to which extent student knowledge is developed from a socio-historic perspective. A typical example of the items in this scale is: "Students learn that science is influenced by people's cultural values and opinions" (Johnson & McClure, 2004, p. 78). To measure the teacher regulation in context-based classrooms we selected the *student negotiation* and *learning to learn*[2] scales from the revised CLES (Johnson & McClure, 2004). Sample items in these scales are: "Students explain their ideas to other students" (Johnson & McClure, 2004, p. 78).

Another instrument that measures learning environments in (science) classrooms is the 'what is happening in this classroom' questionnaire (WIHIC), constructed by (Fraser, Fisher, & McRobbie, 1996). This questionnaire was constructed by "combining salient scales from existing questionnaires" (Dorman, 2003, p. 233) and contains 56 items in seven scales (student cohesiveness, teacher support, involvement, investigation, task orientation, cooperation and equity). Of the seven scales, we expect the *investigation* scale to relate to a KDS emphasis, where

Table 1. Proposed scales to measure a context-based learning environment

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

Origin of scales: [1]Dorman (2003), [2]Johnson and McClure (2004), [3]den Brok et al. (2006)

students learn how scientific knowledge is derived from research. A sample item in this scale is formulated as: “I carry out investigations to test my ideas” (Dorman, 2003, p. 234).

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

To measure the elements of a CBLES we described earlier, we have identified eight possible scales (see Table 1); one to measure context-handling, two to measure emphasis and five to measure regulation. Unfortunately no questionnaire scale has as yet been constructed to measure the aspect of concept transfer (Van Oers, 1998) that is an important element of a CBLES.

CONSTRUCTION AND PILOT

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

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

The two questionnaires (named WCQ-teacher and WCQ-student) were then tested in a pilot study on context-based teaching competencies of teachers that use context-based materials in class. In the pilot study (reported on earlier in De Putter-Smits et al., 2013) the reliability and validity of the WCQ-questionnaires was addressed.

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

First Pilot

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

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

Result. Ten teachers (one physics, three chemistry, five ASMaT, and one biology) varying in the extent to which their classrooms were expected to be CBLES and 163 of their students joined our pilot study and filled out the WCQ questionnaire.

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

Reliability data on items in their original scales are provided in Table 2.

For the CBLES constructs emphasis and regulation the reliability coefficients for all items concerned were 0.86 and 0.90 respectively. The QIB scale strong control is linked to the other two QIB scales in that it does not measure the opposite construct (cf. den Brok et al., 2006). This effect is not apparent when correlating scores

Table 2. WCQ scales – reliability data

Scales		*Number of items*	*Alpha*	
			Original	*Pilot*
Personal relevance		4	0.90	0.85
Investigation		8	0.85	0.83
Uncertainty		4	0.81	0.75
Learning to learn		4	0.85	0.75
Student negotiation		4	0.91	0.87
Strong control		3	0.83	0.78
Shared control		6	0.82	0.81
Loose control		3	0.86	0.78
N	Total		>6000	173
	Teachers		72	10
	Students		>5900	163

with other data such as interviews and classroom observations, where a negative correlation is obtained. We concluded that the QIB strong control scale should be removed from the questionnaire to ensure we measure the regulation construct consistently.

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

Second Pilot – Transfer Scale

A small pilot was conducted for these 14 items among 66 students from two different science teachers, one teaching chemistry and the other teaching physics). A principal component analysis (KM-test indicated adequate sample size) revealed three possible *transfer* sub-scales. One to be interpreted as 'activating previous knowledge', one as 'coherence of concepts within the subject' and one 'using concept learned in new context'. It also revealed two questions needed to be rephrased as they had smaller correlations in their scales. These questions were found difficult to interpret by the students, judging from the remarks on the filled in questionnaires.

One question was considered similar to another question (correlation of almost one) and has been omitted. In all 13 *transfer* items were added to the revised WCQ questionnaire (see Figure 2).

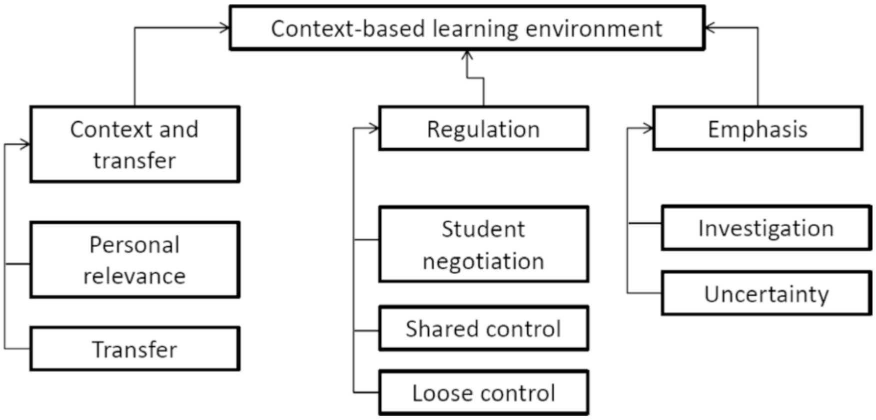

Figure 2. Scheme for the revised WCQ

Experiment

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

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

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

With the model confirmed we then calculated the three context-based scale scores (context-handling, regulation and emphasis) to address the remaining research questions.

An analysis of variance with appropriate post-hoc tests was used in the analysis of teacher and student scores on the different context-based scales to answer the second research question on possible differences per science subject.

The third research question was answered by performing a similar analysis considering the background characteristic of the teacher, i.e. context-based or other material design experience and teaching using context-based curriculum materials. To this end, two open ended questions were added to the questionnaires. One inquiring after the material the teacher used in class and one whether the teacher had (ever) designed curriculum materials and if so to elaborate on the nature of these curriculum materials. The researchers then converted the answers given into three options. For design experience these were: none, general subject related material design (experiments, additional concept clarifications etc.) and context-based material design. For teaching using context-based materials in class they were: only standard book (containing context-references), mixed innovative context-based materials and standard book, and only the innovative context-based material. The influences of the science subject, design experience and experience in teaching using context-based materials on the scores are also analysed for their possible interactions.

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

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

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

To answer our first research question we performed a confirmative factor analysis. This revealed two items should be removed from the questionnaire (due to the much larger sample); one from the investigation scale, one from the student negotiation scale.

The second order factor analysis confirmed the three context-based scales we predicted from literature (see Figure 2). The RMSEA for this model was 0.044, which indicated a good fit of our model. The χ^2-test was significant ($F = 2623$, $df = 655$, $p < .00$). However, since our data set has a large number of respondents ($n = 1630$) this is not an indication that the model is inadequate (Brannick, 1995). The comparative fit index (CFI) and the Tucker Lewis index (TLI) were 0.92 and 0.91 respectively, which indicates a reasonable fit of our model. The standard root mean square residual (SRMR) was 0.046 indicating a good fit of our model. This analysis confirms that the three context-based constructs we identified are measured with this questionnaire.

To ensure all scales together indeed form a coherent measurement of the learning environment, we also performed a second-order confirmative factor analysis (cfa) with one general context-based scale as a second order construct over the original WCQ scales (see Figure 1). This resulted in a reasonable fit for the model (RMSEA = 0.047, CFI-TLI = 0.91–0.90, SRMR = 0.051) confirming our instrument coherently measures the context-based learning environment as expected.

The reliability coefficients for the various scales thus confirmed are given in Table 3.

The WCQ constructs *context and transfer*, *emphasis*, *regulation* and the *total context-based* construct show comparable reliability coefficients for the cases per science subject (see Table 4) making the scores per subject comparable. This allows us to answer our second research question using the three composite scales only.

Table 3. Reliability coefficients for the revised WCQ scales and context-based scales

Scale	*Teachers*		*Students*	
	Alpha	*n*	*Alpha*	*n*
Investigation	0.86	86	0.83	1548
Personal relevance	0.87	83	0.81	1541
Uncertainty	0.75	88	0.71	1551
Student negotiation	0.89	88	0.87	1543
Shared control	0.70	88	0.76	1537
Loose control	0.74	88	0.74	1551
Transfer	0.87	88	0.91	1477
Context and transfer	0.85	87	0.91	1460
Regulation	0.82	88	0.85	1520
Emphasis	0.84	86	0.83	1528
Total context-based	0.89	86	0.93	1413

Table 4. Reliability coefficients for context-based learning environment scales per science subject

Teachers	*ASMaT*		*Biology*		*Chemistry*		*Physics*	
Scale	*Alpha*	*n*	*Alpha*	*n*	*Alpha*	*n*	*Alpha*	*n*
Context and transfer	0.83	15	0.89	23	0.88	23	0.80	26
Regulation	0.76	15	0.77	23	0.81	24	0.84	26
Emphasis	0.83	15	0.70	22	0.88	23	0.84	26
Total context-based	0.86	15	0.82	22	0.92	23	0.89	26
Students	*ASMaT*		*Biology*		*Chemistry*		*Physics*	
Scale	*Alpha*	*n*	*Alpha*	*n*	*Alpha*	*n*	*Alpha*	*n*
Context and transfer	0.92	147	0.91	395	0.91	503	0.90	415
Regulation	0.87	152	0.83	419	0.85	521	0.85	431
Emphasis	0.84	149	0.80	418	0.82	515	0.84	443
Total context-based	0.94	145	0.92	389	0.93	480	0.93	399

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

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

The average student WCQ-scores are shown in Figure 3. For the students' scores the difference between the subjects is significant (one-way ANOVA) for *all* CBLES scales (F-values in Table 5). In terms of effect size these effects are small (Kirk, 1996).

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

Table 5. Significant differences in teacher and student scores comparing science subjects; F-values and ω^2

Scale	*Teachers*		*Students*	
	F(df)	ω^2	*F(df)*	ω^2
Context and transfer	n.s.		06.55 (3, 1559)	0.011
Regulation	n.s.		23.24 (3, 1555)	0.041
Emphasis	3.32 (3, 84)	0.073	13.32 (3, 1568)	0.023
Total context-based	3.49 (3, 84)	0.078	12.93 (3, 1569)	0.022

with $p < .05$

For the *emphasis* scale, the post-hoc Games-Howell test indicated that chemistry students score their learning environment significantly more context-based than ASMaT and physics students on this scale. Furthermore, biology students score significantly higher than physics students (all F-values presented in Table 5).

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

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

Comparing teacher and student scores. As shown in Figure 3, the largest difference in opinion between teachers and students occurs for context and transfer (which influences the total context-based score). The teachers are very optimistic compared to their students. It is therefore difficult to determine what the learning environment for the different subject actually looks like. Calculating the general differences between teachers and students the teachers describe the learning environment they create significantly more context-based than their students for *context and transfer* and *regulation* (with $F(1,1649) = 12.53$, $p < .00$, $\omega^2 = 0.007$ and $F(1,1645) = 10.31$, $p < .00$, $\omega^2 = 0.006$ respectively). They are less optimistic than their students about the learning environment related to *emphasis* (with $F(1,1658) = 14.98$, $p < .00$, $\omega^2 = 0.008$). All effect sizes are small.

This trend continues per science subject with ASMaT teachers scoring the learning environment they create more context-based on *context and transfer*, *regulation*, and *total context-based* (with $F(1,166) = 11.78$, $p < .01$, $\omega^2 = 0.060$; $F(1,166) = 5.88$, $p < .05$, $\omega^2 = 0.028$; and $F(1,166) = 6.36$, $p < .05$, $\omega^2 = 0.031$ respectively). Biology, chemistry, and physics teachers score the learning environment they create less context-based on *emphasis* (with $F(1,445) = 7.35$, $p < .01$, $\omega^2 = 0.014$; $F(1,565) = 4.50$, $p < .05$, $\omega^2 = 0.006$; and $F(1,476) = 7.11$, $p < .01$, $\omega^2 = .013$

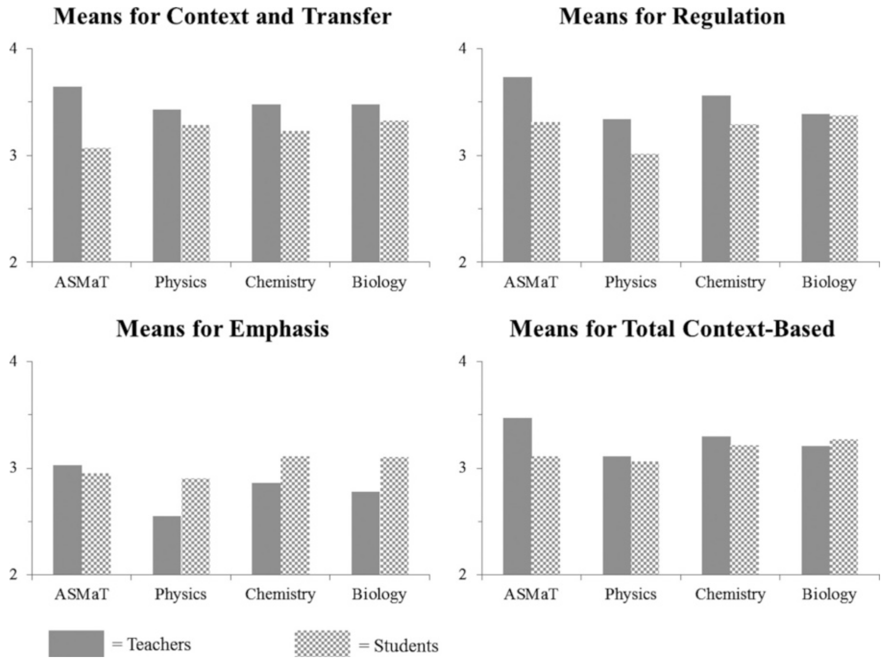

Figure 3. Representation of the differences in WCQ-scores between teachers and students

respectively). Physics teachers score the learning environment they create more context-based on *regulation* (with $F(1,472) = 4.65$, $p < .05$, $\omega^2 = 0.008$). All effect sizes are small.

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

Students score the learning environment they experience for teachers with (any) design experience more context-based than students from teachers without this experience (see Table 6). The effect sizes are small. Design experience in subject related material has more influence on the WCQ scores than context-based design experience. This trend is visible for all science subjects apart from ASMaT, where (any) design experience has a negative influence on the WCQ student scores (see Figure 4). From Figure 4 it is apparent that for biology there are no teachers with 'design experience in subject related material' in our sample.

Table 6. Influences on student WCQ scores: Design experience and method (F, df, and ω^2)

Scale	*Design experience*			*Method*		
	F	*df*	ω^2	*F*	*df*	ω^2
Context and transfer	3.92	(2, 1546)	0.004	25.36	(2, 1546)	0.030
Regulation	4.87	(2, 1542)	0.005	22.26	(2, 1542)	0.027
Emphasis	n.s.			25.44	(2, 1555)	0.030
Total context-based	4.06	(2, 1556)	0.004	24.99	(2, 1556)	0.030

From the analysis for the materials used in class (standard text book, mixed materials, context-based materials only) a significant test result from the teachers' perspective was obtained for all CBLES scales. A post-hoc Hochberg test indicated that for all four context-based scales students who use mixed-materials scored significantly higher than those who use a standard book. Also the use of context-based material scored significantly higher on the scales for *regulation*, *emphasis*, and *total context-based* than the use of a standard book. For the *context and transfer*

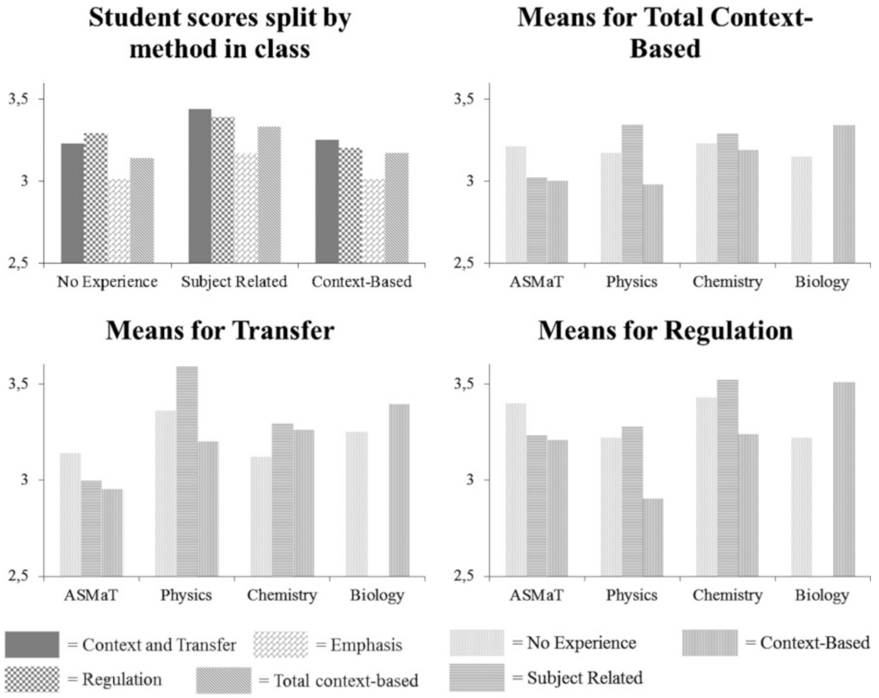

Figure 4. Student scores separated by design experience of their teacher and by subject

scale $F(2,84) = 4.21$ ($p < .05$) with $\omega^2 = 0.069$, for the *regulation* scale $F(2,84) = 5.95$ ($p < .01$), with $\omega^2 = 0.10$, and for the *emphasis* scale $F(2,84) = 6.39$ ($p < .01$), with $\omega^2 = 0.11$. In terms of effect size these effects are medium.

On the *total context-based* scale $F(2,84) = 9.81$ ($p < .00$) with $\omega^2 = 0.17$, which is a large effect size.

The corresponding analysis on the student data revealed significant results for all CBLES scales (see Table 6). When mixed materials are used in de class, the scores on all CBLES scales are significantly higher than either when only context-based materials are used or when only a standard book is used. For the *regulation* scale the use of context-based materials has a significant effect on the WCQ score in preference to the use of a standard book. For the *context and transfer* scale the use of context-based materials only has a significant negative difference in WCQ score versus the use of a standard book.

To eliminate the possibility that this effect is due to the nature of the subject taught (biology, chemistry and physics)[3] we used subject as covariate in an ancova. Similar results were obtained with the differences significant with $p < .01$). The student WCQ scores per subject per scale are given in Figure 5.

Interestingly, the area where the school is situated also appears to have an influence on the learning environment. Students from schools from the 30 largest cities in the Netherlands score significantly lower on three of the WCQ scales than

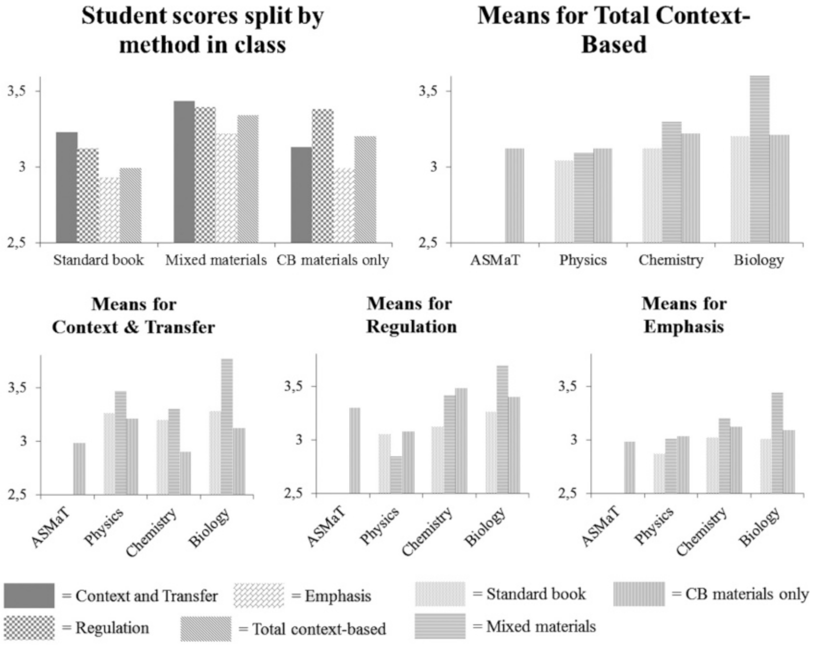

Figure 5. Student scores separated by the method used in class and by subject

students from schools in more rural areas. Teachers in urban areas show stronger regulation ($F(1,1557) = 6.75$; $p < .01$; $\omega^2 = 0.004$) and a teaching emphasis closer to fundamental science ($F(1,1557) = 10.86$; $p < .01$; $\omega^2 = 0.005$).

CONCLUSION AND DISCUSSION

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

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

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

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

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

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

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

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

The instrument could be useful in future studies into context-based learning environments (CBLES) in other countries. Comparative studies can be made using this instrument in combination with interviews and other research methods into the differences in teaching science subjects in different cultures.

The subject specific findings could be the starting point of future research to uncover how the different science subjects could attain a CBLES. Also changes in CBLES in science classrooms could be monitored, should the Dutch Government instate the context-based curricula that have been constructed and tested.

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NOTES

[1] Considering the practical argument that long questionnaires might be filled in less seriously by students, we chose to use the version of the CLES constructed by Johnson and McClure (2004).

[2] Originally this scale is called 'shared control', however due to the similar name of the QIB scale we use another term for this scale that is mentioned in Johnson and McClure (2004).

[3] For ASMaT, only context-based materials are available.

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8. INTERACTION BETWEEN TEACHERS AND TEACHING MATERIALS

Creating a Context-Based Learning Environment in a Chemistry Classroom

INTRODUCTION AND OVERVIEW OF THE STUDIES

Creating context-based learning environments has appeared to be quite a difficult problem (Pilot & Bulte, 2006). For teachers it involves a change in pedagogical approach and content to teach within a new vision on the goals and emphasis in science education. The research described in this chapter focuses on the implementation on factors that hinder or facilitate the implementation of innovative context-based teaching materials in classroom practice by senior chemistry teachers who are not familiar with context-based education. A framework to rigorously analyse and understand the interaction between teachers and new teaching materials in context-based science education in the process of curriculum innovation is not available. Either, the researchers perspective is solely on the design of teaching materials, or researchers focus on teacher's classroom behaviour. There seems not to be much research in which these foci are combined; how do teachers create a learning environment based on teaching materials that follows an approach new for them?

In this chapter, we will first develop a framework to structure data collection and data analysis in the light of these research foci. This framework was built to allow in a valid, reliable and practicable way the identification of factors in the design of the materials, in the opinions and activities of teachers and in the interactions between teachers and materials (Vos et al., 2010). Then, using this framework we will study which factors facilitate or hinder adequate implementation. Finally we present implications for teachers, teacher educators and researchers.

This framework was applied in a series of case studies (Vos, 2010; Vos et al., 2009, 2011). The teaching materials selected for the cases were all extensively tested in practice beforehand and represented features of context-based learning environment in a well-thought-out format. Using such materials allowed a focus on factors in the interaction between senior teachers and innovative materials without the risk that only the (poor) quality of the materials would hinder implementation. Senior teachers were selected to prevent lack of teaching experience interfering

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with the implementation of new innovative teaching materials. In each set of cases, the implementation processes adopted by the participating teachers have been described as individual cases. Together, the various case studies involved nine senior teachers (nine cases, Table 1) with different degrees of experience of context-based learning environments. They implemented a context-based learning environment in their classroom practices, using teaching materials with which they were not familiar and for which they were offered no specific extra professional development activities.

The first study (Vos, 2010) involved three cases (teachers) and took place in the Netherlands when a national discussion with teachers took place on a curriculum change from traditional into context-based science education. It focused on the implementation of a context-based teaching unit, designed to teach 16–17-year-old students about scientific inquiry and writing a scientific paper. These senior teachers had no previous experience of context-based education.

The second study (Vos et al., 2009, 2011) involved four cases and took place in Germany on the implementation of materials designed and tested in the 'Chemie im Kontext' project (CHiK), national project on context-based education. The four senior teachers differed in degree of experience of CHiK. These case studies looked at the effect of previous experiences with this context-based approach and the way it is implemented in classroom practice.

The third study (Vos, 2010), involving two cases, investigated the effect of the growth of context-based experiences on implementation. Two senior teachers in the Netherlands were selected who had implemented the selected unit in the year(s) before. This unit is part of a series in which a new unit is developed every year on another scientific topic but in the same format. The unit in this study was of the same series as in study 1, but other teachers were involved.

In this chapter first a short description is given of the methodological aspects of the research presented. The procedure for data collection and data analysis is summarized, together with the theoretical basis of the analytical framework. This is followed by a reflection on the findings, i.e. on the four factors which are formulated in answer to the main research question. This chapter also presents recommendations for five groups of stakeholders to whom this research is relevant.

Table 1. Overview of the nine cases

	Unit 'Learning to Inquire'	*CHiK-units*
Senior teachers without experience of context-based education	Teachers 1-I, 1-II and 1-III (first study)	Teachers 2-III and 2-IV (second study)
Senior teachers with previous experience of context-based education	Teachers 3-I and 3-II (third study)	Teachers 2-I and 2-II (second study)

THE ANALYTICAL FRAMEWORK

To investigate the implementation process a framework for analysis was developed (Vos et al., 2010) that structures the data collection and data analysis in a series of case studies (Vos, 2010; Vos et al., 2009, 2011). This section reflects on the framework's theoretical features to indicate its value after use in nine cases.

Main Features of the Analytical Framework

The main feature of the framework is that it consists of two dimensions, combined into a nine-cell matrix. The *horizontal dimension represents* '*curriculum representations*' *and the vertical dimension shows* '*levels of thinking and acting*'. The nine cells of the framework are filled to describe the implementation process in terms of '*curriculum emphases*' and '*instructional functions*'. The use of each of the four theories in the framework is summarized, indicating its value for studying the implementation of innovative context-based materials.

		Levels of Thinking and Acting		
		Theoretical level	Descriptive level	Ground level
Curriculum Representations	Intended curriculum as presented to teachers	① ***Intended Emphasis*** Designers' objectives underlying the teaching materials	② ***Intended Teaching-Learning Strategy*** Operational & instructional goals incorporated in the structure of the unit	③ ***Intended Activities*** Instructions to the teachers meant to incite specific teaching activities
	Perceived curriculum	④ ***Perceived Emphasis*** Objectives as recognised and as intended by the teacher to be implemented	⑤ ***Perceived Teaching-Learning Strategy*** Practical and instructional considerations of the teachers about the strategy	⑥ ***Perceived Activities*** Activities that automatically follow from the materials according to the teachers
	Operational curriculum	⑦ ***Shown Emphasis*** The objectives according to which teaching takes place, (observations & interview)	⑧ ***Shown Teaching-Learning Strategy*** Followed strategy as observed in classroom	⑨ ***Shown Activities*** Activities shown while teaching based on routines and intuition of the teacher

Figure 1. The analytical framework represented as a matrix

Concept of Curriculum Representations

The analytical framework is developed to evaluate the transition of teaching materials into classroom practice. The concept of curriculum representations is a broadly accepted theory on implementation that is commonly employed for this purpose (Goodlad, 1979; Van den Akker, 1998; Kuiper, Boersma, & Van den Akker, 2005; Gilbert, 2006; Pilot & Bulte, 2006; Van Berkel, Pilot, & Bulte, 2009). It served to define ‘implementation as intended’. Implementation is considered adequate if all representations are aligned with each other (McKenney, Nieveen, & Van den Akker, 2006). Incorporating curriculum representations in the framework allowed (in)coherencies to be determined between the intended, perceived and operational curriculum, i.e. between the three rows of the framework.

Levels of Abstraction for Thinking and Acting

The levels of abstraction for the teachers’ thinking and acting as described by Van Hiele (1986) can be used to describe the various types of information that are made available for the teacher within the teaching materials to guide their implementation in classroom. In an adaptation of Van Hiele’s level theory, which was originally developed to describe students’ learning of mathematics, we distinguished the *ground, descriptive and theoretical levels* (cf. Korthagen & Kessels, 1999). On the ground level, teaching activities are considered to be based on routines linked to experiences with concrete situations previously encountered without conscious reflection. On the descriptive level, teaching activities are considered to be conscious and organised in such a way that they serve operational goals within a teaching-learning strategy. On the theoretical level, reflection can be considered as a process of theory formation and application, creating behavioural and operational thinking guided by theory-based conceptions of chemistry education.

The levels of abstraction for thinking and acting served to specify the definition of ‘implementation as intended’. Implementation is considered adequate if all curriculum representations align with each other on all three levels of thinking and acting. Represented in the framework as columns, the three levels are employed to determine the extent of coherence within the design, the perceptions and the practice, i.e. within the distinct curriculum representations. Coherence within each curriculum representation (rows in framework) means that (instructions for) teaching activities on the ground level align with the teaching-learning strategy on the descriptive level which logically results in the emphasis targeted on the theoretical level.

Curriculum Emphases

The concept of curriculum emphases (Roberts, 1982) is used to identify both designers’ and teachers’ perspectives regarding the focus on content of context-based materials and to evaluate how these perspectives are used to create a specific kind of learning environment in classroom. Each emphasis consists of a coordinated set of messages to be communicated which reflects the view on chemistry itself, society, the learner and the teacher. We have concluded that the transition of content-oriented chemistry education towards context-based chemistry education essentially involves a shift in emphasis away from the ‘Fundamental Chemistry’ emphasis (FC) and towards the 'Chemistry, Technology and Society' (CTS) and 'Knowledge Development in Chemistry' (KDC) emphases. Teaching according to the FC-emphasis results mainly in a theory-driven learning environment in which the book and the teacher indicates what the important concepts are. Teaching in the perspective of the CTS-emphasis means that the teacher attempts to create a need-to-know environment based on societal and/or technological issues. Within the KDC-emphasis the learning environment is meant to let the students experience the process of knowledge construction via student regulated activities.

Instructional Functions

'Instructional functions' as described by Vermunt and Verloop (1999) and Shuell (1996) are used to identify the focus on learning and teaching in context-based education: *the teaching strategies for reaching the emphases*. This gives an enriched view of how a particular emphasis can be translated into concrete teaching activities, surpassing the gap between the abstract concept of curriculum emphases and the concrete teaching activities. Instructional functions are components that have to be fulfilled for effective education, in combination being conceived as a teaching-learning strategy that should result in a specific learning environment according to a specific emphasis. The distinguished instructional functions are 'motivation', 'orientation', 'activation prior knowledge', 'acquisition', 'application', 'reflection' and 'assessing/monitoring'.

METHODOLOGY

The procedure for data analysis is structured in four steps, the first three steps focusing on one of the three rows of the analytical framework and comprising data gathering, data coding and data interpretation. The fourth step involves a birds' eye overall perspective. This section provides a summary of the main features of each step.

Step 1: Analysis of the Intended Curriculum

The first step focuses on the intentions behind the materials as presented to the teachers, answering questions concerning the cells of the intended curriculum (upper row in Figure 2). It serves to check the coherency in the design of the teaching materials under study. Analysis comprises document analysis and an open interview with the main designer about the philosophies and design principles. This step also involves the identification of critical episodes. Comparing the three cells indicates if there are incoherencies in the design which may pose barriers to adequate implementation.

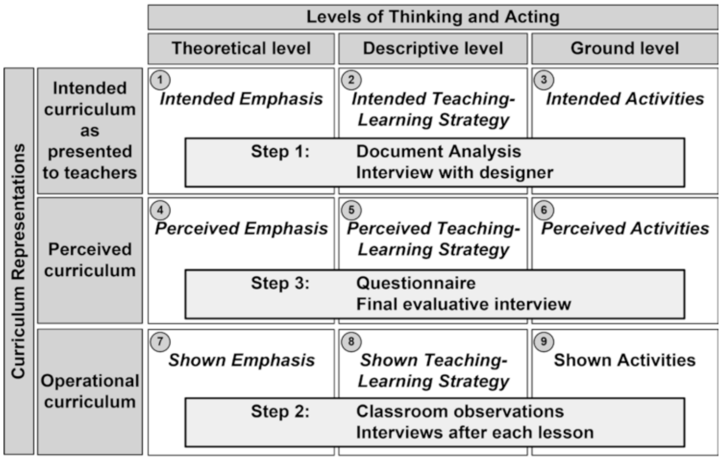

Figure 2. Procedure for analysis showing the first three steps

Step 2: Analysis of the Operational Curriculum

The second step focused on the operational curriculum and how the teaching materials are used in classroom practice (bottom row of Figure 2). Data are video- and audio-recorded classroom observations and interviews with teachers after each lesson, when they were invited to explain their teaching. The critical episodes are given particular attention for comparison with the results of the first step to check the adequacy of implementation. This is to determine coherence between the intended and operational curricula.

Step 3: Analysis of the Perceived Curriculum

In the third step, answers were given to questions concerning the perceived curriculum (middle row in Figure 2). This step is meant to reveal perceptions of teachers about the materials and their use in practice. An in-depth evaluative interview with teachers and a questionnaire on teaching emphasis (Van Driel, Bulte, & Verloop, 2005) are the data sources.

Step 4: Bird's Eye Perspective

Each of the three steps led to an evaluation of the relations between the cells in the row in question with respect to coherency. Finally, what can be seen as the fourth step, a bird's eye analysis, was applied to all nine cells. Adequate classroom implementation is threatened by any discrepancy between two distinct cells.

If all cells are coherent with each other, implementation can be considered as ideal. Incoherencies between cells indicate factors hindering adequate implementation.

An analysis first describing the implementation process in nine distinct cells and then the relation between these cells appeared adequate and of added value in finding characteristics hindering or facilitating implementation. Incoherencies between two distinct cells indicated the kind of problems teachers faced during implementation. Incoherencies between the cells on ground level indicated a deficit with respect to adequate concrete instructions or adequate concrete skills. Incoherencies in the cells of the descriptive and theoretical level indicated problems in communication on that level in terms of understanding the materials and value congruence. An incoherent design of the materials was not found although critical episodes are identified which indicate barriers to implementation.

REFLECTIONS ON THE FINDINGS: FACTORS HINDERING OR STIMULATING THE IMPLEMENTATION

The nine case studies resulted in the identification of four factors with respect to teaching materials, teachers and their interaction, each influencing implementation in a specific way (Vos, 2010). This section summarizes the outcomes and gives a reflection on the meaning and relevance of the findings. For each factor, a short description is given, reflecting its major statement. Next, the relevance of the factor in relation to the main research question is shown by reference to the findings in the nine cases and to recent findings in the literature. The description of each factor is concluded with a recommendation for smooth implementation of context-based teaching materials and by eliciting how this factor answers the main research question.

Factor 1: Coherent Design of the Teaching Materials

A prerequisite factor for adequate implementation is a coherent design of the materials on all three levels of thinking and acting. A coherent design means that rationale and emphasis (theoretical level), teaching guidelines regarding the teaching-learning strategy (descriptive level) and presumed teacher activities (ground level) all are aligned. If the design is incoherent with respect to these aspects, this will cause confusion for teachers and students and hence will hinder adequate implementation. Coherency in design demands that implementation of the intended classroom teaching activities and teaching-learning strategy will result logically in the desired emphasis. For instance, addressing the instructions in the materials without knowledge of the intended teaching-learning strategy or emphasis should still result in accomplishment of the intentions on all levels. If the materials show incoherency in the use of emphasis, instructional functions and instructions for activities, teachers and students will be confused and implementation as intended will be hindered.

The necessity of a coherent design was a key assumption from the very beginning of this research. For this reason we selected teaching materials with a well-described format and extensively tested in practice. The expectation was that if teaching materials were implemented adequately previously, they were probably coherently designed. Interviews with the designers and document analysis of all materials provided to the teachers were employed to check for the expected coherent design or to identify incoherencies that posed barriers to adequate implementation.

Although only teaching materials with an expected coherent design were studied, even in such units incoherencies occurred in particular parts of the materials. The importance of this factor for adequate implementation is shown by the critical episodes in which the coherent design was not unambiguously present. Adaptations during implementation by the teachers especially in these episodes imply an obstacle to the coherent design of the materials. The intentions have to be presented to the teachers unambiguously, otherwise teachers might interpret them differently and as a consequence implementation will not be as intended. In study 1 (Vos, 2010), for instance, it appeared that the function of a particular assignment was not unambiguously clear to the teachers, and could be interpreted in the light of the KDC emphasis as well as the FC emphasis. Consequently, during implementation it was found that teachers were confused about what was most important. Instead of focusing on aspects concerning 'learning to inquire' the teachers tended to put extra focus on 'chemical content'.

In the literature it is found that teaching materials with an incoherent design result in implementation which will not be as intended. In particular, an inconsistent use of emphasis, addressing multiple emphases at the same time, causes much confusion and will result in inadequate implementation (Van Berkel, 2009; Bulte et al., 2005). Bulte et al. indicate that more than one curriculum emphasis is allowed to be present in context-based materials, although they should not be mixed up. 'No abrupt or implicit changes are to be made, in order to prevent inconsistent 'what', 'why' and 'how' messages' (Bulte et al., 2005, p. 277). By selecting only (nearly) coherently designed materials we did not investigate this further empirically.

Contexts are at the core of context-based learning environments and how these are used is critical in providing coherency in the design of the materials. We consider two aspects important.

First, the context addressed in the teaching materials should offer a clear indication of the emphasis aimed at and the concepts to be learned should have a clear meaning in the context. For instance, the context of the unit in studies 1 and 3 concerns the authentic practice of making students to do inquiry as researchers, which fits clearly with the intended KDC emphasis.

Second, the context should provide a well-defined behavioural environment (Gilbert, 2006) which is logically connected to a focal event. In that case the teaching-learning strategy will be closely connected to the chosen context. Hence, selecting a context with a clear focal event supports a coherent design by serving as a point of orientation for the classroom activities which then will lead to the intended emphasis. Therefore, both teachers and students will feel that the sequence and content of the activities are logical and are likely to follow them. In study 3 (Vos et al., 2009, 2011), the contexts used in the CHiK materials were too general to be effectively applicable as a setting in which intended activities of students and teachers logically arise.

Factor 2: Support and Skills on a Concrete Level

The way in which teachers implement the materials on ground level is inter alia dependent on the extent to which the teachers' routine-based skills are adequate for the intended teaching activities and on the adequacy of the support embedded in the materials via concrete suggestions. Without an adequate implementation of concrete teaching activities on ground level, the intended teaching-learning strategy cannot be deployed and the intended emphasis cannot be realised. Such is the case if instructions do not adequately support teachers in the implementation of concrete teaching activities and if teachers do not have a repertoire of routine-based teaching activities available and adequate for context-based teaching.

Context-based education requires teachers to use a new set of teaching activities. The role and task of the teacher are strongly influenced by this approach to chemistry education. For instance, instead of transferring knowledge in the role of an instructor employing teacher-controlled activities, the teachers have to get used to teaching activities in the role of coaches facilitating students' self-regulated learning. It appeared that senior teachers, being new to context-based education, face difficulties in abandoning their old behaviour in the light of the requirements of context-based materials. One of the teachers attempted to use the context to motivate and orientate the students but when the students did not seem to engage with the subject and did not employ self-regulated activities she fell back on teaching activities in front of the classroom.

Hence, adequate classroom implementation will only occur if teachers have the required skills on ground level. This requires learning. In order to be able to build new skills, teachers have to experience what context-based teaching requires of them (Stolk, Bulte, De Jong, & Pilot, 2009). Therefore, they must first be able to translate materials in practice (Ball & Cohen, 1999).

For positive experiences on which to build, the materials to be developed should make use of a detailed design of concrete teaching activities in such a way that teachers intuitively sense what should be done. Teachers' key concern is what to do in the classroom (Van den Akker, 1994; Deketelaere & Kelchtermans, 1996). Their activities on ground level are routine-based and directly influenced by classroom reality. Teachers without experience of the new approach do not have the overview of the complete unit and may lack the theoretical and descriptive knowledge of context-based education to determine what kind of teaching activities are required. Hence, they adhere to their old routines without adaptations or they stick to the assignments and tasks exactly as presented in the materials.

This means that the design of the materials should be so robust that activities follow logically and intuitively. The tasks (instructions for concrete activities) have to support teachers to adapt their old routines to the requirements of the new materials or to learn new skills adequate for context-based teaching. Teachers' instructions, especially for the first lessons, should be understandable and directly applicable (at ground level). Support should include the basic activities needed for implementing the context-based unit and result in lessons as intended.

One of the difficulties in the design of teaching materials is the dilemma concerning the amount of instruction: if instructions are too strict teachers may lose their sense of ownership; if instructions are lacking, teachers do not know what to do (Pinto, 2005), with the likely result of falling back on old routines that conflict with context-based education. The observed teaching materials contain a moderate amount of ground-level instruction, leaving what to do at the concrete classroom level to the teachers. The general section of the teachers' guide of CHiK provides suggestions for different kinds of classroom activities which can be used by the teachers; which one to use is left up to the teacher, however (Vos et al., 2009, 2011). The tasks in the first lessons of the unit on learning to inquire (Vos, 2010) do not support the teachers in adapting their routine-based behaviour. It is quite possible for them to pick up suggestions that the old way of teaching still suits, without a need to change. Once the focal event was established in the classroom, however, this did guide the activities of students and teachers towards the intended implementation. This focal event, which is also central to the work of research communities, implies a number of activities with which teachers and students feel so familiar that they intuitively know what is expected of them.

Hence, we conclude that teachers need to have a repertoire of skills suitable for context-based education and that instructions on a concrete level are necessary to support teachers in adapting their routines and learning to apply new skills. It is essential to select a context which teachers can easily recognise and understand and with which they feel familiar and comfortable in such a way that they intuitively know what to do. A context representing a well-known focal event will provide the teacher with a knowledge base that helps to guide the students in their self-regulated activities. The focal event of 'inquiry' in some of the cases was well known by the teachers involved and this evoked behaviour relevant to these cases. This might not be so easy in modelling or designing as focal events (cf. Prins, 2010; Meijer, 2011).

The design of context-based teaching materials should make the focal event so explicit that teachers will recognise it as the core of the unit and keep it as the focus of classroom activities. It is therefore important that the focal event is unambiguously presented at the very beginning of a unit. The focal event will provide the structure in which instructions are embedded and concrete teaching activities will logically take place in such a way that new routines will be facilitated and teachers will obtain positive experiences.

Factor 3: Competence in Understanding the Materials

Teachers must have the competence to understand the rationale and strategy to be able to implement and to adapt the materials as intended. The competence to understand the materials is defined as the ability to recognise the intended emphasis (cell 1), the intended teaching-learning strategy (cell 2) and its implications for classroom practice. In other words, a teacher must be able to link intentions with what will happen in classroom practice. Teachers' understanding of the materials is influenced by their ability to reflect critically on their own classroom behaviour and to relate this to intentions recognised within the materials (Korthagen, Loughran, & Russell, 2006).

As stated before, teachers' initial concern is what to do in the classroom (Van den Akker, 1994; Deketelaere & Kelchtermans, 1996), especially when they are implementing new materials for the first time.

After their first experiences with the materials in classroom practice, however, teachers will become more aware of vision, content and pedagogy, which will affect their teaching. Even though teachers might have succeeded the first time in implementing the materials adequately, it does not guarantee that this remains the case during the following cycles of application if the competence to understand the materials is lacking. Whereas in the first cycle teachers tend to follow ground-level instructions, in the second cycle they will be more inclined to follow their own directions instead of the instructions. Adaptations can only be adequate when teachers' understanding of the materials is good enough to keep these adaptations within the overall intentions for the unit. When their understanding is weak, however, it is likely that they will make the wrong decisions, changing the unit in a way that makes the unit incoherent with the original design. This became very clear in study 3 (Vos, 2010). Both teachers adapted the planning of the unit on the basis of their experiences in previous years. One of the teachers showed a clear understanding of the teaching-learning strategy in the unit; he kept the focal event as the core of the unit, a point of orientation and motivation for the students. Another teacher, however, wanted to make sure that students did first fully acquire the required knowledge base by continuing to discuss it before moving on. He was not aware that the meaning of this knowledge is founded in the focal event. By focusing on the acquisition of knowledge without a direct relation to the focal event, the spine of the teaching-learning strategy was lost. Owing to a lack of understanding this teacher made decisions which were not in line with the intentions of the teaching materials.

It is also known from the literature that teachers must be aware of and understand the meaning of the changes in the new materials before they are able to direct their teaching activities in such a way that implementation remains as intended (Davis & Krajcik, 2005; Harland & Kinder, 1997; Remillard, 2000). Awareness of the implications of the new approach in comparison with the traditional ones has to grow to reach sustainable change. This is in line with Van Driel et al. (2005), who stress that teachers should be able to recognise the emphasis, strategy and activities and that they have to know how to apply these in their teaching practice.

Understanding of the teaching materials is important for realising sustainable change in classroom practice, but this has to be facilitated. First, it is important that all crucial aspects are communicated to the teachers explicitly, and in such a way that they know which aspects they have to realise in order to implement the context-based approach as intended and which aspects they are allowed to adapt to the needs of their specific situation. This means that the teaching materials should not only contain ground-level instructions (to facilitate factor 2) but should also contain communication on the rationale and teaching-learning strategy. As Remillard (2000, p. 347) states: 'Curriculum materials should 'speak to' teachers about the ideas underlying the tasks rather than merely guiding their actions'. The characteristics of the units' design are then used as a learning object, providing important positive experiences of the effects of the new approach. This makes high demands of the new materials; the teaching materials should be designed to be educative for both teachers and students (Ball & Cohen, 1999; Davis & Krajcik, 2005; Schneider, Krajcik, & Blumenfeld, 2005).

If it is not possible to communicate the rationale via the materials, extensive teacher professionalization is required to provide teachers with an opportunity to develop a full understanding of the approach. This is especially important if the approach represents a complex design integrating multiple aims and views on learning and motivation of students. Furthermore, it is important that teachers should gain experience of the new approach in such a way that awareness and understanding of the new characteristics will grow. Therefore, teachers should start implementing the new materials in combination with professional development linked to their experiences. Critical reflection is needed on what is different from the traditional approach. This can also be achieved by communities of practice, which provide teachers with the opportunity to exchange experience, reflect on their teaching and gain feedback from peers (Dobber, Akkerman, Verloop & Vermunt, 2010; Vandyck, Graaff, Pilot, & Beishuizen, 2010). Coaches who should be available in such communities can guide the teachers to a higher level of understanding.

Factor 4: Value Congruence

Value congruence is defined as coherence between teachers' and designers' values in aspects regarding teachers' role, students' learning, content, and how this content should be taught. Teachers' values are built from personal and professional experience and affect their decision-making, planning and execution of teaching activities. Designers' values are represented in the teaching materials and indicate the goals and content aimed at and the strategy intended to teach this. Value congruence refers to the teachers' perceptions of the materials and the classroom practice, and the degree to which these overlap with the intentions.

It is widely known that teachers' values and beliefs influence implementation, consciously and unconsciously (Coenders, 2010; Pajares, 1992; Yerrick, Parke, & Nugent, 1997). Teaching practices are shaped and framed by teachers' beliefs, especially their beliefs about learning, teaching, and the nature and purpose of whatever they are teaching. Teachers tend to incorporate new programmes into a largely unaltered practice because their ways of thinking about their practice are more closely linked to their belief system than to the new curriculum mandates (Moore, Edwards, Halpin, & George, 2002; Yerrick et al., 1997). Context-based education requires the vast majority of teachers to reconceptualise their teaching practice and to teach new content in a new way. As Harland and Kinder (1997) assert, the presence of value congruence is needed to bring changes in classroom practice. Knowledge alone is not enough (Fairbanks et al., 2010).

First of all, teachers are required to adapt the teaching materials to the specific demands of the situation in which they are teaching. Their personal values will guide their decisions. A teacher might understand the intentions underlying the materials, but if these intentions conflict with his/her conceptions of chemistry education, implementation might result in a classroom practice more closely linked to personal conceptions than to designers' intentions. Teachers' beliefs will filter their interpretations of the intended curriculum, as well as their ultimate implementation of the curriculum in classroom practice (Yerrick et al., 1997).

Second, it is known that adaptation of the materials during implementation occurs unconsciously. In classroom practice, teachers often have to interpret the meaning of a situation and to decide, within a split second, how to act, an often unconsciously made decision in which their needs, feelings, values, conceptions and so forth take part (Korthagen & Kessels, 1999). Hence, in this situation their values concerning chemistry education also guide their decisions and although these decisions take place unconsciously, it is especially important that value congruence exists between those of the teacher and those represented in the materials.

The teachers involved in the case studies showed that value congruence is an important factor in facilitating implementation as intended. It appears, however, that this factor influences implementation differently for teachers completely new to context-based education and teachers who have some previous experience of context-based education. It appears that if inexperienced teachers, to whom the unit is new, use ground-level instructions without the intrusion of their own values system, the implementation will be as intended (Vos, 2010, p. 142) but teachers with previous experience tend to adapt the unit to a certain extent, according to their experiences, understanding and values (Vos, 2010; Vos et al., 2009, 2011). If value congruence existed, implementation was much more likely to be as intended than if this was not the case. Specifically when teachers adhere to values that are incongruent with those of the designers, this is quite problematic.

Value congruence appeared to be important for adequate implementation and is required for sustainable change in classroom practice. Teachers must be given the opportunity to examine their values and those represented in the materials. Communities of practice with fellow teachers can provide opportunities to discuss what they see as important for chemistry education.

RECOMMENDATIONS BASED ON THE FINDINGS

Recommendations based on the findings are given for three groups of stakeholders: teachers, teacher educators, and educational researchers

Recommendations for Teachers

Teachers are the main users of the teaching materials. With regard to the way in which these materials are implemented the concerns and activities of teachers are of crucial importance (Bakkenes, Vermunt, & Wubbels, 2010). The introduction of context-based materials requires teachers to reconceptualise their thinking about teaching chemistry and to abandon certain aspects of the way they used to teach. Although most teachers are experienced, starting context-based teaching requires learning. It also provides new opportunities, for instance, that of learning new chemistry content by working with new contexts based on recent developments. On the basis of the four factors, recommendations are formulated.

The first is that teachers starting context-based education should select representative teaching materials known to be coherently designed and carefully tested by others. In Germany, such is the case for the CHiK handbook. In the Netherlands, units can be found that have been extensively tested and revised in several cycles to optimise the design, and that are representative for exemplary context-based programmes (‘leerlijnen’). Although these materials may be in a well-defined format, teachers should not hesitate to adapt them to the requirements of their specific situation. In doing so, however, they should bear in mind that adaptations need to remain coherent within the unit. Consequently, designers should have indicated what is critical for the unit and what is suitable for adaptation.

Second, teachers should practice the skills required for context-based education by experimenting with context-based units. They should give themselves the opportunity to learn how to use these new teaching materials and to adapt their routines to the requirements of the new situation. The best way to learn new skills and adapt old routines is by experiencing what context-based education means in classroom practice. Experience should be built up by first testing one single, well-designed unit in the regular programme, before attempting to use a completely new curriculum. In this way, positive experiences with new teaching activities can be strengthened before more units are incorporated. This involves much less effort, which will promote motivation and willingness to innovate and will prevent teachers from falling back into old routines. A teacher must have the willingness and motivation to invest energy in a certain way of teaching. Small discrepancies, for example, between teachers' vision and practice, may generate the motivation to learn. Large discrepancies, however, may discourage learning and lead to withdrawal, despair, or frustration (Shulman & Shulman, 2004). Implementing a complete curriculum at once requires teachers to be active at all levels of thinking and acting, dealing with abstract aims and vision while also learning to employ new teaching activities.

The third and fourth factor prompts the recommendation to invest (time and effort) in professional development, especially via communities with fellow teachers. Teachers need time for discussion and reflection for a period of at least one year, preferably two or more, in order to learn from their experiences with the new approach. Teachers should claim this time. Communities of teachers should work on meaningful activities, aiming at understanding and value awareness, such as developing and designing teaching materials. This will result in teaching materials recognisable to teachers and closely linked to their belief systems. It will also help teachers to develop their thinking about curriculum materials and empower them to shape their own classroom practice by being able to make good decisions about changes in the curriculum materials and to adapt these to the reality of their specific classroom practices (cf. Barab & Luebmann, 2003; Davis & Krajcik, 2005; Stolk et al., 2009).

Recommendations for Teacher Educators and Professional Development

It can be expected that in future context-based education will be an important way to teach science. Teacher education institutes should play a crucial role in the innovation process by providing facilities for teacher learning. Pre- and in-service teachers require specific training before they can implement context-based education adequately, because they did not experience such education in their own years at school.

First teacher education programmes should ensure that these new teachers learn to understand the key aspects in the design of context-based teaching materials: the vision and arguments for this type of education, the design principles and frameworks and the new content areas involved like food, materials, pharmaceuticals and technology. Teaching materials should be discussed on vision and teaching-learning strategy in order to be able to determine on a concrete level which teaching activities best fit the specific demands of classroom reality. In our view, a good way to learn about the meaning and implications of these aspects is to incorporate (small-scale) design activities in the programmes, such as redesigning parts of teaching materials which appeared inappropriate during the discussions.

Second, teacher education should provide (pre-service) teachers with the specific skills required for context-based education. Context-based education implies that new teaching activities should be related to students' active and self-regulated learning, e.g. scaffolding, working in groups, and stimulating reflection on learning activities. The teacher has to learn how to facilitate students' learning processes instead of transmitting a static body of knowledge. This demands a high degree of flexibility to incorporate the new teaching activities appropriate to specific moments.

On a meta-level teacher education and teacher professional development should help teachers to develop a positive attitude towards educational innovation. Teachers must have a certain vision of teaching and student learning, and must understand the concepts and principles on which new approaches to teaching are based (Shulman & Shulman, 2004). As education changes almost continuously, teacher education institutes should be involved in organising peer communities of learning for their alumni in order to stimulate and facilitate further development beyond their initial learning at the institutes. This can be done in the form of networks of teachers providing opportunities for exchanging expertise and experiences, e.g. as members of learning communities with other teachers within and outside school.

Recommendations for Educational Researchers

It is probable that we did not describe all the factors influencing implementation. From the very beginning of this research the focus was on the interaction between teachers and teaching materials. This implied that teaching materials are viewed from the perspective of the designers who are developing the materials and from the perspective of the teachers who have to work with these materials. Beyond the scope of this research but significant in terms of influence on implementation are issues regarding school organisation (management, facilities, time, etc); these affect the facilitation of the teacher and the requirements for implementation of context-based education in school practice. Also beyond the scope of this research were the students who are active participators in context-based education. Students have a major impact on how classroom practice is shaped by bringing in their expectations of the lessons and the way they are used to work. Aspects of context-based education such as student-controlled activities imply major changes to which students have to become accustomed. Hence, further research from a wider perspective will probably provide a better understanding of other factors influencing implementation of context-based chemistry education.

Some questions remain, however, with regard to the two perspectives which were the focus of this research. These issues will be further elaborated. First, adequate implementation requires a coherent design with embedded instructions at a concrete level (see factors 1 and 2). How contexts are interpreted and employed is crucial. Further research is required to determine the design principles needed to employ contexts as effective focal events and the criteria governing selection of the best context to serve the intended learning goals. Research into design principles for context-based education on the basis of authentic practices can be found in Prins (2010), Meijer (2011) and Gilbert, Pilot, and Bulte (2011).

Second, to achieve sustainable change in classroom practice teachers are required to have a high understanding of the rationale behind context-based education. It is also important that they are aware of their own values and those represented in the materials. As mentioned earlier, teachers are facing an extensive learning process in which they have to learn how to implement innovative teaching materials and also how to gain ownership of their teaching practice. The learning process of teachers was not, however, the focus of this research. Further research is required into how teachers' professional development can best be facilitated in school practice. Professional development trajectories seem promising in which teachers are part of communities in which there is a possibility to exchange experiences and to provide peer feedback, and in which they also employ meaningful activities like designing teaching materials (Stolk et al, 2009; Coenders, 2010).

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9. SUPPORTING TEACHERS TO TRANSFORM THEIR CLASSES INTO A CONTEXT-BASED LEARNING ENVIRONMENT

Inquiry as a Context

INTRODUCTION

Context-based approaches in science education, such as context-based chemistry or physics are gaining ground. For example, in The Netherlands new context-based curricula have been developed for the natural sciences,[1] which will be implemented in the years to come (SLO, 2010). However, in order to create effective context-based education, teachers will need to change the classroom culture, the social norms and forms of interaction that shape classroom practice (Cobb & Yackel, 1998). In contrast to the traditional classroom culture based on knowledge transmission, students in context-based curricula will have an active role. In these classrooms there will be an emphasis on the social nature of learning processes, and on activities that reflect essential aspects of authentic situations (Gilbert, 2006). Teachers will need to develop professionally to acquire the knowledge, skills and attitudes needed to transform the culture in their classrooms in line with these new requirements (Hewson, 2007; Pintó, 2005). Providing teachers only with new teaching materials will generally not bring about the desired change of teaching practice (Fullan, 2001; Vos, 2013), because even with support, many teachers may not adopt the pedagogy behind the teaching materials (Van Driel, Verloop, Van Werven, & Dekkers, 1997).

A promising way to create successful innovation is to involve teachers in the development of reform based lessons and lesson materials (Coenders, Terlouw, Dijkstra, & Pieters, 2010; Stolk, De Jong, Bulte, & Pilot, 2011). Being involved in the design process may help teachers to acquire the subject knowledge and pedagogical understanding required to enact the lessons and for the lessons to address teachers' educational concerns. Moreover, teacher learning is expected to be fostered by co-designing and enacting lessons, because it creates a sense of ownership and stimulates reflection (Coenders, 2010; Pintó, 2005). In this chapter we will describe a professional development process in which three secondary school physics teachers

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and a researcher, the first author, were involved. Collaboratively the teachers and the first author designed a series of lessons with the aim to bring the classroom practice of the teachers more in line with context-based education and in particular, to establish a culture of inquiry in their classrooms. The lessons were enacted by the teachers in their regular classes. In our research on this intervention, the aim was to understand how participating in the process led to professional development of the teachers in terms of reported learning and changes of the classroom culture. We will describe the professional development processes of each teacher as separate cases and discuss common themes among the three cases. The lessons resulting from the intervention are also subject to research. As a cycle in an Educational Design Research (EDR) project (Gravemeijer & Cobb, 2006) we will study which factors foster student understanding of theoretical concepts in physics when a culture of inquiry is created in the classroom. In this chapter we focus on the professional development process of the three physics teachers. The study of the lessons will be published separately.

CONTEXT-BASED EDUCATION IN THIS CHAPTER

Several authors identified problems in the traditional science curricula, such as the overload of topics and concepts, the teaching of science as a collections of isolated facts, the lack of transfer of science learning and the lack of perceived relevance of the curriculum (Gilbert, 2006; Osborne & Dillon, 2008). The use of curricula based on contexts has been proposed as a way to overcome these problems. According to Duranti and Goodwin (1992) a context involves a focal event, that is, the phenomenon being contextualized, and a field of action in which the focal event is embedded and which gives meaning to the event. Gilbert (2006) described the function of context in education as follows:

> Thus, the function of “context” is to describe such circumstances that give meaning to words, phrases, and sentences. A context must provide a coherent structural meaning for something new that is set within a broader perspective.

Using attributes of educational contexts identified by Duranti and Goodwin (1992) in combination with theories on learning, Gilbert (2006) transformed these attributes into criteria to evaluate models of contexts relevant to chemistry education. As he formulated these criteria in a way that is not specific to chemistry education, they can be used to evaluate models of context in the other natural sciences as well:

1. A context has to include an authentic situational setting, which must be valued by the students and provide the framework for a community of practice in the classroom.
2. The student tasks must bring about a behavioural environment in which students can interact with relevant subject related concepts.

3. The students have to be helped to develop subject specific language related to the focal event
4. Students have to be given the opportunity to relate focal events to extra-situational background knowledge.

To structure the ways contexts are used in education, Gilbert described four models, with increasing compliance to the criteria. In the first two models of context the emphasis is on an authentic situation arising from the student life-world, from the worlds of professional and academic work, or from contemporary issues. In the last two models, the emphasis is on context as activities in which students participate, either individually or collectively. One possible perspective on the fourth model, which comes close to meeting all the criteria, is "a context as social activity" in which students' learning is fostered by participating in a community of practice. Gilbert (2006) observed that a course design using "context as a social activity" is infrequently found, "perhaps because of the resource demands that it makes, for example, on teachers' subject knowledge and pedagogical content knowledge. As an example of this model Gilbert referred to Realistic Mathematics Education (RME) (Cobb, Stephan, McClain, & Gravemeijer, 2001). In RME the teacher's aim is to establish a culture of inquiry in the classroom (Cobb & Yackel, 1998) by negotiating relevant classroom social norms, and subject specific social norms. In line with these norms, teacher and students develop subject specific practices, allowing students to learn mathematics by a process of guided reinvention. Cobb and Yackel (1998, p. 158) emphasize that "the culture established in a mathematics classroom is in many ways analogous to a scientific research tradition". The starting point in RME is a situation that is *experientially real* to the students (Cobb, Yackel, & Wood, 1992; Freudenthal, 1981), which does not refer to a context that corresponds in all aspects to a situation in the students' life-worlds, but rather to an educational setting in which the students can act and reason sensibly.

A scientific research tradition is also relevant in a physics learning environment in which the context is formed by the social activities of the participants. However, teachers need to develop professionally to create the required culture of inquiry in their classrooms. The professional development process described in this chapter had the aim to help the teachers establish a culture of inquiry in their classrooms in which students would be facilitated in coming to understand concepts of electricity in simple direct current circuits. No genuine academic inquiry was aimed for (as the physics behind these circuits has long been known), but rather a meaningful simulation of inquiry processes at the level of the students (Hung & Chen, 2007).

INQUIRY

In science education the term *inquiry* can mean different things (Minner, Levy, & Century, 2010). In their review study Minner, Levy and Century compiled essential characteristics of inquiry instruction in science education:

- it engages students with scientific phenomena, either directly or through secondary sources
- it emphasizes active thinking and student responsibility for learning
- it emphasizes student motivation (e.g. by building on student interest, curiosity, involvement or focus)
- it uses at least some part of the investigation cycle (pose questions, design investigations, process and interpret data, draw conclusions, communicate).

As there are various ways to create instruction with these characteristics, we describe in general terms the type of instruction envisioned in this project. The instruction had the purpose of allowing students to experience a meaningful simulation of, in the words of Latour (1987), "science in the making". During the lessons, groups of students would engage with the relevant phenomena through theoretical and experimental investigative tasks and through computer simulations. Tasks would call for explication of student ideas, reasoning and explanations, rather than for factual recall or for solving calculation problems. Ideas would be presented and brought together in teacher led class discussions which would have a prominent place in the lessons. The amount of lesson time devoted to teacher explanations and student work on standard text book problems was expected to be greatly reduced as compared to traditional lessons.

The topic of the lessons, theoretical concepts in electricity, is generally considered difficult for secondary school students (Duit & Von Rhoeneck, 1998; Shipstone, 1985; Taber, de Trafford, & Quail, 2006). An earlier study indicated students cannot be expected to rediscover these concepts through inductive experimental activities (Kock, Taconis, Bolhuis, & Gravemeijer, 2011). Developing understanding through experiments and developing a theoretical understanding need to go hand in hand. To be able to develop a theoretical understanding, students need to be provided with theoretical tools, language and symbols. Based on the results of the earlier study we suggested that students be provided with the essence of a theoretical model, such as a model of moving charge, through which they could engage in theoretical talk. We considered this an authentic approach to inquiry, as also in physics research experimental work is often induced by theoretical considerations (Park, Jang, & Kim, 2009).

Student inquiry activities need to be carefully prepared, otherwise students are unlikely to construct the desired conceptual understanding. This applies in particular to an abstract and complicated topic such as electricity. Anticipating how students will come to construct understanding requires a theory of how relevant student learning processes might evolve and on how these learning processes might be evoked and fostered. Thus, instructional activities have to be created as part of a *conjectured local instruction theory* (Gravemeijer & Cobb, 2006): a sequence of "instructional activities, and a conjectured learning process that anticipates how students' thinking and understanding might evolve when the instructional activities are employed in the classroom".

TEACHER PROFESSIONAL DEVELOPMENT

Professional development is defined by Fullan and Stiegelbauer (1991) “the sum total of formal and informal learning experiences throughout one’s career from pre-service teacher education to retirement”. Interventions in this area can be regarded as activities with the purpose to improve the quality of teachers, their instruction and the learning of their students (Van Veen, Zwart, Meirink, & Verloop, 2010). Professional development activities are often seen as a precondition for educational innovation, because innovations require teachers to take on a new role and change their practice (Borko, Jacobs, & Koellner, 2010; Vos, 2010). However, many professional development activities do not lead to lasting changes of teaching practice (Fullan, 2001). In a recent review study Van Veen et al. (2010) synthesized characteristics of professional development interventions that successfully led to a change of classroom practice. In a literature study on teacher learning in collaborative curriculum design Voogt et al. (2011) came to similar characteristics. We list the most important of these:

- The intervention is preferably related to specific teacher concerns and teachers are involved in the aims of the intervention, problem formulation and analysis
- The content of the intervention is directed towards subject content, subject didactics and the learning of students.
- Teachers learn actively and can contribute their own experiences, exchange experiences and collaborate with colleagues.
- Teachers are exposed to actual classroom practice and coaching takes place after the initial training.
- Professional development is directed at teams of teachers rather than at individual teachers.
- A substantial amount of time is available for the intervention.

Van Veen et al. (2010) further noted that the interplay of these characteristics and issues of school organization and facilitation have an impact on the effectiveness of a particular intervention. In this study we intended to create an intervention with these characteristics. However, the setting of the intervention did not allow us to work with teams of teachers from the same school. Instead, we worked with teachers from three different schools.

DESCRIPTION OF THE INTERVENTION

The professional development intervention we describe in this chapter was facilitated by the first author, who had eight years of experience as a physics teacher and three years as a teacher trainer. The purpose of the intervention was to change the practice of the participating physics teachers. More specifically, the aims were:

1. To collaboratively design and enact a lesson series in which a culture of inquiry would be created in the classroom that would help students understand the theoretical concepts in simple electric circuits.
2. To create learning opportunities for the teachers so that they would come to understand the physics content of the lesson series in relation to the pedagogy and learning environment we aimed for, and their role in it.

As participants we recruited volunteer physics teachers from a part-time Master of Education (Med) program at Fontys University of Applied Sciences in The Netherlands. Teachers from this program were given the opportunity to combine participation in the intervention with their practitioner research project, the final obligatory part of the MEd program. We expected this arrangement to be beneficial for the participants, so that it would compensate for the required investment in time and effort. In terms of teacher professional development, the participants had the opportunity to develop knowledge, attitudes and skills relevant for creating a culture of inquiry in their classrooms. Moreover, the lesson series they would co-design was expected to increase the conceptual understanding of their students on the topic of electricity. Teachers could participate if they taught a grade 9 class in the pre-university stream of education in which lessons on electricity were to be enacted, if they were interested in the topic of electricity and in inquiry as a context, and if they were prepared to relate their practitioner research to a particular interest or concern regarding the teaching of electricity. The participants were provided with relevant research literature, received guidance and could benefit from group discussions and joint data collection. The time investment asked from the teachers to participate in the intervention was to a large extent be covered by the time allocated for their practitioner research projects. This eliminated the need for additional facilitation, for example by the respective schools. Meetings could be easily organized as the teachers visited the university on a weekly basis for the MEd program.

The phase of the intervention in which instruction was designed consisted of collaborative group meetings between the teachers and the first author. The content of these meetings was as follows:

1. A detailed discussion of the physics concepts and the student conceptual problems in the grade 9 curriculum on electricity. The purpose of this discussion was to (a) increase awareness that the topic of electricity is difficult for students, (b) arrive at a common vision of the understanding expected from the students at the end of the lesson series and (c) share ideas and experiences on how students' conceptual understanding could be improved. Relevant research literature and an overview of student conceptual problems known from the research were provided to the participants.
2. A discussion of how a model of moving charged particles (electrons) could be used at the level of grade 9 students to explain the theoretical concepts and the phenomena related to simple electric circuits. An earlier round in the design research project (Kock et al., 2011) suggested that students' theoretical thinking

and talking could be fostered by providing students with a basic theoretical model. The model we decided to use bears resemblance to the model suggested by Licht (1987). The discussion included the common metaphors used in teaching electricity and made connections with models based on the electrical field concept, beyond the grade 9 level. From the University of Colorado (University of Colorado, 2010) a number of interactive computer simulations were available on the internet that illustrate different aspects of a charged particle model.[2] It was discussed how these simulations could be used in the lessons. The discussion resulted in a written summary of the model prepared by the first author.

3. Discussion of a pedagogy suitable to create a culture of inquiry in the classroom. A number of aspects were discussed: the use of models, the importance of students' ideas, subject specific practices such as students' active involvement in explanations and reasoning, the use of language and symbols and how experiments could be related to theory. An earlier round in the design research project (Kock et al., 2011) suggested that in order to successfully create of a culture of inquiry in the classroom, it was important to find a balance between the freedom for students to investigate and the structure provided by the teacher and the teaching materials, and to find a balance between the development of a scientific motive and the existing school motives. So, we discussed how a new classroom culture could be initiated by the teachers and what concrete measures could be taken in the lessons to maintain these balances. A written summary was made of the discussion.
4. Design of the instructional activities as part of a conjectured local instruction theory. The local instruction theory capitalized on the model of moving charged particles and contained a sequence of preplanned experimental and theoretical tasks and activities. It was developed in the course of several meetings. After each meeting the first author elaborated the results of the discussions into a lesson outline for the teachers and, in a later stage, into worksheets for students. In the subsequent meeting the lesson outline and worksheets were discussed by the group and amended if necessary.
5. Additional topics: the assessment of the lesson series and practical issues related to logistics.

After the enactment of lessons had started, brief feedback and evaluation meetings took place (approximately 10 minutes) between the teacher and the first author. If such a meeting was not possible due to the teacher's time table, the lessons were evaluated during the group meetings. The group meetings further focused on preparation of subsequent lessons, extensions or modifications to student materials and the teacher's role. In terms of EDR these aspects of the meetings can be considered micro cycles of evaluation and design (Gravemeijer & Cobb, 2006). Where possible, enactment of the lessons took place in the presence of the first author, who occasionally assisted in the enactment of the lessons, for example by helping groups of students who were working on tasks and, on request of the teacher, by contributing during whole class discussions. The purpose of this assistance on the one hand was to model aspects of the pedagogy for the teachers and on the other hand to help create the classroom culture necessary for the lesson study.

Recruitment in the MEd program during September 2009 resulted in the participation of three teachers. The group meetings started in December 2009 and lasted until July 2010. A total of 19 group meetings were held, lasting between 30 minutes and two hours, in which each teacher participated for approximately 15 hours. The first teacher enacted the lessons in March/April 2010, the two other teachers in June/July 2010. The meetings ended when all three teachers had enacted the lesson series. Thereafter, the teachers continued working individually on their practitioner research projects.

RESEARCH QUESTIONS

We expected the participating teachers would learn to change their classroom practice towards a more context-based approach, in particular towards an approach with a 'context as social activity'. To understand how participation in the professional development process gave rise to teacher learning, we posed the following research questions:

1. What learning did the teachers report after participation in the collaborative lesson design and enactment?
2. To what extent did the teachers change their classroom practice?
3. How can the reported learning and the teachers' classroom practice be related to participation in the professional development process?

METHOD

Participants

Three physics teachers from a group of 11 MEd students at the Fontys University of Applied Sciences volunteered to take part in the professional development process. The teachers, Mr. Adler,[3] Mr. Bradley and Ms. Campbell, taught at three different secondary schools in the south of the Netherlands. The school where Mr. Adler taught was located in a medium-sized town and had an urban character, while Mr. Bradley and Ms. Campbell taught at schools in smaller towns in the urbanized countryside. Mr. Adler had been a physics teacher for 19 years; Mr. Bradley had been a physics teacher for 9 years, after working for 17 years in the automotive industry; Ms. Campbell was in her second year as a physics teacher, after working as a library assistant at the school for several years. All three taught grade 9 classes in the pre-university stream of their school. Mr. Adler and Ms. Campbell decided to enact the experimental physics lesson in one of their classes and teach the usual school curriculum in the other class. Mr. Bradley decided to enact the experimental lessons in 2 of his classes and the usual school curriculum in the other 2. Class sizes varied between 20 and 25 students.

Data Collection and Analysis

Data collected during the intervention consisted of video recordings of all group meetings, agendas, notes, e-mails, teachers' proposals for practitioner research and two interviews of 10–20 minutes with each of the teachers. One interview took place shortly after the enactment of the lessons in 2010, a second interview in the first months of 2011 after two of the teachers had enacted the lesson series for a second time. Also included were the reflections Mr. Bradley and Ms. Campbell wrote at the end of their practitioner research projects, as they contained remarks about their learning. We video recorded one lesson of each teacher before the enactment of the experimental lessons to have an example of the teachers' "normal teacher practice". Further data on the classroom practice consisted of video and audio recordings of lessons (for technical reasons one lesson could not be recorded), field notes by the first author, interviews with three randomly selected students per teacher directly after the lesson series and a student questionnaire administered immediately before and after the lesson series. The questionnaire contained among others 22 items on how students experienced aspects of the learning environment in the lesson series on electricity as compared to the physics lessons before this lesson series. The items were related to student activity, inquiry, self-directedness and cooperation, consisting of statements such as: during physics lessons I carry out experiments; in physics lessons I discuss with other students how to solve problems. Students indicated on a scale from 1 (never) to 5 (very often) how often the situation in the statements occurred.

The items were adapted from the questionnaire by Blumberg (2008), with a few items added from the Constructivist Learning Environment Survey (Taylor, Fraser, & Fisher, 1997). Before the lesson series students were asked to focus on their usual physics lessons ($\alpha = 0.91$) and after the lessons to focus on the lesson series on electricity ($\alpha = 0.92$).

To arrive at case descriptions for the three teachers we followed a stepwise procedure of data reduction. Based on the agendas, notes, video and audio recordings, we made a descriptive summary of all meetings (group meetings and evaluation meetings after the lessons) in terms of the activities that had taken place and the topics that had been discussed. To process video and audio data, we used the f4 transcription software (Burgdorf, 2010). Time stamps in the summaries referring to the video and audio files allowed the different sections of the summaries to be traced back to the original recordings. Similarly, we made descriptive summaries of all lessons based on the video and audio recordings and on the teacher's field notes. Teacher and student interviews were transcribed. Data on the teachers from the interviews, e-mails, proposals and reflections were organized in matrix form

(Miles & Huberman, 1994). The matrix contained information on the teacher background, self-reported teacher learning and reflections about the professional development process as a whole. The next step of the analysis was to use the summaries to make brief descriptions of each teacher's lessons with regards to the following aspects of context-based education and inquiry: situational setting, student interaction with subject specific concepts and language, responsibility for learning, level of activity and participation, level of cooperation among students, instructional methods used by the teacher. We included information on coaching by the first author, teacher reflections after the lesson and student interview data in the descriptions. Using these characterizations of the lessons, the matrices with teacher data, the student questionnaires and the original data sources where necessary, we were able to describe each teacher's case following a roughly chronological order.

A number of measures were taken to ensure reliability of the results, which was especially important as the first author acted both as a facilitator of the intervention and as a researcher. First, we used data triangulation by taking data from various complementary sources: video and audio recordings, teacher and student interviews, a questionnaire and additional documents. Second, in the case descriptions we referred to the original data sources, so that the statements we made can be traced back to these sources. Third, results in various stages of the analysis were discussed by all authors of this chapter. Fourth, a member check was carried out. Comments made by the teachers after reading the case descriptions were incorporated in the final version of the text. In fact, only minor modifications were necessary.

CASE DESCRIPTIONS

Summary information about the three teachers and their participation in the professional development process is shown in Table 1. Mr. Bradley and Ms. Campbell had started the experimental lessons in May, which limited the maximum available number of lessons due to the start of the summer vacation. For Mr. Adler this limitation did not apply as he had started the lesson series in March. Mr. Adler's

Table 1. Overview of the three cases

Case	*Physics teaching experience*	*Grade 9 Physics classes*	*Number of experimental lessons*	*Lesson by lesson evaluation*
Mr. Adler	19 years	1 experimental 1 non-experimental	13	12 after lessons and 5 group meetings
Mr. Bradley	9 years	2 experimental 2 non-experimental	11	2 after lessons and 4 group meetings
Ms. Campbell	2 years as teacher 9 years as tutor	1 experimental 1 non-experimental	12	1 after lessons and 5 group meetings

time table made it possible to have a brief preliminary evaluation meeting after each lesson, apart from the weekly group meetings. Mr. Bradley's and Ms. Campbell's time tables did not allow for these meetings, so that a first evaluation of the lessons took place during the weekly group meetings.

In the sections below we describe the three cases of Mr. Adler, Mr. Bradley and Ms. Campbell. Throughout the text we refer to the different data sources in the following way: (SI) student interviews, (TI) teacher interviews, (O) lesson observations, (M) meetings, (D) documents.

The Case of Mr. Adler

At the time of the intervention Mr. Adler taught two grade 9 classes in one of which he tried out the experimental lessons on electric circuits and in the other taught his usual lessons on this topic. His usual lessons typically consisted of teacher explanations (often calculation examples) of which students made notes. Occasionally students worked on problems. An initial lesson observation showed a classroom atmosphere in which students were used to ask questions if something was not clear, or to come forward with their ideas if prompted. In the opinion of an interviewed student, the teacher explanations were easier to understand than the explanations in the text book. (SI, O).

Mr. Adler had three concerns he wanted to address in the experimental lessons. First, he usually took for granted that approximately one third of the class would not understand the topics he taught. However, for the experimental lessons his aim was that all students would participate and reach an acceptable level of understanding (M). Second, he was unhappy with his present use of metaphors in the lessons on electricity. He had the impression the metaphors limited student understanding. (M) Third, he wanted to use the experimental lessons to experiment with forms of group work, to enrich his repertoire of teaching methods and because he believed students' understanding of electrical circuits would increase if students in small groups interacted and solved problems together (D, TI).

To start creating a culture of inquiry, Mr. Adler told the class in the first lesson that their ideas and contributions, also if not immediately correct, could help the class to solve problems and could lead to common understanding. He kept encouraging students to listen to each other's ideas, to exchange their ideas, and that together the class had the ability to solve problems and obtain explanations. He also pointed out that students were responsible for active participation (for example that he was not going to provide them with single correct answers to conceptual problems) (O). In the lesson evaluation meetings Mr. Adler was encouraged to keep taking student ideas as a starting point for discussions. After the third lesson he remarked that the interactions during class discussions gave him insights into students' ideas that were not available through his usual teaching method (M).

To help all students in the class to come to understand electric circuits, Mr. Adler involved many students in the class discussions, in particular those who found physics difficult and those who were generally not motivated for the subject. He adapted the lesson planning and kept returning to a topic until he had the idea all students had reached a sufficient level of understanding (M, O). The perceived level of student understanding was discussed during the after-lesson evaluation meetings. In comparison to his other class the teacher noticed a higher ability of students in the experimental class to reason about electric circuits. He also noticed an increased level of student motivation and participation and even found students explaining physics problems to each other at school in their own time (M). Audio recordings of student groups during lessons indicated students saying they were more active in these lessons. A small group of students (mostly girls) often remained after classes to keep discussing what they had not understood. Mr. Adler thought this engagement might partly be caused by students seeing these lessons as an opportunity to get a good grade, which would enable them to choose physics in their subject package in the following year (M). When giving tasks and leading class discussions the teacher focused on understanding physics in terms of the particle model, explaining phenomena and making predictions before experiments were carried out or simulations were shown (O). Students started talking about electric circuits in terms of the particle model, especially during class discussions. Occasionally, Mr. Adler was insecure about his application of the particle model (for example whether or not to define current as the speed of electrons) or was unable to respond to student questions (in particular where the model reached its limits such as in the explanation of what happened inside a battery). Aspects of the model were again talked about during after-lesson evaluations and group meetings (O, M). During class discussions he used various computer simulations and encouraged students to predict and explain their working. Occasionally the first author intervened in the classroom to clarify confusion about the particle model or the limitations of the simulations (O).

A number of practical investigations had been prepared with an emphasis on research questions to be answered by the students, rather than recipe-type procedural experiments focusing on obtaining correct measurement values. The research questions and topics of the practical investigations were given in the student worksheets. Mr. Adler provided the students with additional structure by pointing out the focus of the experiments and conducting class discussions in which students were asked to predict in theoretical terms what the outcomes of the experiments would be (O). He considered the way students carried out the experiments (e.g. by making correct circuits and placing meters correctly in circuits without receiving explicit instruction on how to do this) as a sign they knew what they were doing (M).

In retrospect Mr. Adler remarked that the lesson series, and observing a colleague teaching the same topic in a more traditional way, had made him realize teacher explanations did not help much to increase students' understanding of electric circuits. He added it was more effective to let students think together about how things work and to let them explain phenomena to each other, either in groups or in whole class discussions. He had also come to the conclusion that it is very difficult to teach the topic of electricity without using at least some metaphors (apart from the particle model), but was aware that it is important to indicate the limitations of these metaphors to the students. Mr. Adler was in doubt whether the student experiments contributed enough to student understanding. He still had the impression that theory and experiment were two different worlds for most students and suggested the experiments could be made more open ended. In general this teacher was pleased with the collaboratively developed lessons and teaching materials, although he was concerned students who had missed lessons were not given a complete explanation of the theory in the worksheets (TI).

Students had noticed that the experimental lessons had been different from their usual physics lessons. Two girls, interviewed after the lessons said they had been more active than in the usual physics lessons. They also said the class discussions, and the higher demands made on their own thinking had contributed to their conceptual understanding. Two interviewed boys mentioned in particular differences in the type of tasks and the increased number of experiments. That is, the boys reported in particular differences related to the design of the lesson series and not so much to the classroom culture (SI). Results of the student questionnaire indicated Mr. Adler's students experienced a significantly higher constructivist orientation in the experimental lessons on electricity (N = 21, M = 66.5, SD = 12) as compared to their usual physics lessons (N = 20, M = 55.9, SD = 12) using related-samples Wilcoxon signed ranks test (T = 12.0, p = 0.001, r = 0.53). The effect size of 0.53 can be considered a large effect (Cohen, 1992). In particular, the responses to items on the questionnaire showed Mr. Adler's students experienced they cooperated more with other students, carried out more experiments, had more opportunities to investigate things by themselves and had more opportunities to develop their own ideas.

Approximately nine months later, Mr. Adler repeated the lesson series with a new grade 9 class. More than during the first enactment, he experimented with different types of group work. He had also made sure to take enough lessons to enact the lessons series and not to rush through the content. In his view, the response of the students was similar to the first enactment. But in general he was more satisfied with the approach, as he felt more prepared for the questions that came from the students and knew better "where he wanted to go" (TI).

The Case of Mr. Bradley

At the time of the intervention Mr. Bradley taught four grade 9 classes in two of which he tried out the experimental lessons on electric circuits, while he taught his usual lessons on this topic in the other two classes. His classes typically consisted of teacher explanations, student work on text book problems, and approximately one experimental activity per chapter or topic. While solving text book problems, students usually worked together in small groups. In a lesson observed before the start of the experimental lessons on electricity Mr. Bradley introduced a new topic (heat related phenomena). In this lesson he used various instructional methods: a brief demonstration of heating water, with the purpose to evoke student prior knowledge on heat, a class discussion guided by (Socratic) teacher questions, teacher explanation and student work on problems (O, SI).

In Mr. Bradley's view the aim of the lessons was to improve students' conceptual understanding of electric circuits, such that they could express their ideas on the relevant theoretical concepts in a scientifically correct way. In his opinion just carrying out calculations using Ohm's Law did not lead to real understanding. Moreover, he wanted students to see the connection between the physics lessons and the real-life world. For example students would ideally have an understanding of what happens when a light is switched on. Mr. Bradley called this the "concept-context story" (TI). He had the impression the experiments students carried out in traditional lessons on electricity did not contribute much to conceptual understanding. He expected the use of computer simulations that visualize what happens inside an electric circuit in line with the particle model used in the experimental lessons, could improve students' understanding. In particular, he expected that the use of computer simulations in which students could see what happens inside a circuit, in combination with hands-on experiments, would help students relate experiments to theory and develop scientific conceptions (D).

In the first lesson, Mr. Bradley explained to the class how the way of working in the lessons on electric circuits would differ from his usual lessons. The class was going to use and gradually extent a theoretical particle model to explain the phenomena taking place in electric circuits. Students were going to carry out experiments, exchange ideas, discuss and learn from each other. Mr. Bradley encouraged students to be actively involved and look for solutions. All contributions were welcome to help the understanding of the class forward. He told the class the work of physicists had similar characteristics: theories are built through many different contributions that gradually lead to consensus. During the lessons the teacher conducted a number of class discussions, which were characterized by Socratic type questioning. In a group meeting after the second lesson Mr. Bradley was encouraged to see if these discussions could be built more around student ideas. He let students work in groups, on conceptual questions set in the student worksheets and in most lessons the student groups used computer simulations and/or carried out experiments. Problems the groups did not finish during lesson periods were set as homework (O). In general Mr. Bradley consistently used the particle model, showing only some hesitation in discussing student questions transcending the limitations of the model, such as questions related to the processes inside a battery and how rechargeable batteries work (O, M). Occasionally during class discussions, the first author intervened, for example to model the use of questioning (e.g. by asking students to predict what was going to happen before switching on a simulation).

Mr. Bradley said he had to get used to the approach of the experimental lessons. Initially the lessons felt chaotic to him and he sensed a lack of structure and progress. He sensed also the students had to get used to the new method. During group work he did not find them engaged and he had the idea they did not develop an attitude of inquiry. These observations were discussed during the group meetings and collaboratively ways were sought to increase student engagement and make their work more effective. For example Mr. Bradley started to give students different roles during group work (scribe, time keeper, etc.) after Mr. Adler had told about his positive experiences with this approach (M, O). For Mr. Bradley the opportunity to exchange experiences and ideas with other physics teachers was one of the benefits of the collaborative lesson preparation and the group meetings (TI).

In retrospect Mr. Bradley mentioned working with the theoretical particle model as one of the things he learned. In his view it was important to start with a simple model which was gradually extended, while students used simulations and experiments to verify the model and connect it to their existing knowledge. Another thing he had learned was to keep students actively involved in the lessons by asking the right questions. He had noticed that the more he was “on top of it”, the more engagement he saw with the students (TI). Mr. Bradley remarked some ideas he initially had about student learning had turned out incorrect. For example the computer simulations, in spite of the fact that they visualized otherwise invisible aspects of electric circuits, did not immediately clarify the theoretical model for the students. He had come to the conclusion that the use of computer simulations has to be accompanied by specific student tasks in order to contribute to student understanding (D). Moreover, Mr. Bradley had expected the tasks on the worksheet were clear for the students without further explanations, but found in reality they were not. He suggested the worksheets could be written more clearly on some places. Finally, he had the opinion that physics culture could have come more to the fore in the lessons, but that more specific ideas on how to do this would have to be included in the lesson preparation (TI).

Interviewed students, especially the girls, had noticed the experimental lessons had been different from their usual physics lessons. One boy did not see a lot of difference in the teaching methods. However, he appreciated aspects of the lesson design: the incremental pacing and the use of simulations and experiments. Three girls appreciated the discussions in peer groups, in particular, as one girl remarked, because explanations by the teacher were usually directed to boys who were better at physics. The girls also appreciated the simulations and experiments, and the lack of calculations and formulas. The lessons had not changed their opinion of physics as a subject (SI). The questionnaire showed the students in Mr. Bradley’s two classes experienced a significantly higher constructivist orientation in the experimental lessons on electricity as compared to their usual physics lessons. Results from the related-samples Wilcoxon signed ranks test are shown in Table 2.

The effect sizes of 0.39 and 0.38 can be considered medium effects (Cohen, 1992). In particular, as in the case of Mr. Adler’s students, the responses to items on the questionnaire showed Mr. Bradley’s students experienced more cooperation with other students, carried out more experiments, had more opportunities to investigate things by themselves and had more opportunities to develop their own ideas.

Table 2. Mr. Bradley's students' judgement on the lessons on electricity in comparison with their usual physics lessons (using Related-Samples Wilcoxon Signed Ranks test)

Class	*N pre*	*Pre Mean (SD)*	*N post*	*Post Mean (SD)*	*Test Statistic T*	*p*	*effect size r*
1	24	60.9 (13)	22	68.5 (12)	77.0	0.009	0.39
2	23	61.9 (13)	14	68.9 (7)	46.5	0.045	0.38

However, the students in one class considered the experimental lessons less relevant for the world outside school than their usual physics lessons.

Approximately 6 months later, Mr. Bradley enacted the lesson series again with a new grade 9 class. He felt the second enactment was easier, because he knew what was going to happen. He felt more able to encourage the students, for example by emphasizing that student contributions did not necessarily have to be correct to be valuable for the class as a whole. As he sensed his students were insecure, because in the new lessons they had a higher responsibility for their own learning, he showed students the progress they had made after a few lessons. During his second enactment of the lessons, the focus for Mr. Bradley was even more on making students explain and discuss the physics to each other in theoretical terms. To this end he kept asking questions, while his whole class explanations were kept to a minimum.

Mr. Bradley proposed to his colleagues to use the experimental lessons as the standard way of teaching introductory electricity in the school. However, his colleagues did not like the absence of calculations in the experimental lessons. They considered these calculations necessary to prepare students for the physics lessons of the 10th grade. Moreover, they were critical of the model of charged particles used in the lessons. They considered this model incomplete and suggested that concepts such as the electrical field would have to be included. The end result of the discussion was that the experimental lessons were not used as a model for the school, but that Mr. Bradley could use them in his lessons.

Reading educational research literature on student conceptual problems related to electricity confirmed Mr. Bradley's idea that the topic of electricity is difficult for students. From taking part in the project he learned that instruction, in order to be successful, has to take student learning as a point of departure, instead of the content as presented by the text book. However, no perfect instruction for the topic of electricity has been found yet. In the end he considered the experimental lessons equally successful as his usual approach and a welcome variation for the students (D, TI).

The Case of Ms. Campbell

At the time of the intervention Ms. Campbell taught two grade 9 classes in one of which she tried out the experimental lessons on electric circuits, while she taught her usual lessons on this topic in the other class. According to her students, physics lessons of this teacher typically consisted of brief theoretical explanations, after which students worked in groups on text book problems. During this work, Ms. Campbell walked from group to group, making sure the students remained on task and answering student questions. Usually unfinished problems would be set as homework. To help students prepare for tests, she provided a summary of the theory on the board, briefly before the date of the test. According to one student these summaries were a very useful part of the physics course (SI, O).

Ms. Campbell was aware that electricity is a difficult subject for students. Getting better insight into students' conceptual problems and finding ways to help students understand the concepts of electricity were her concerns (TI, D). Moreover, she said she was open to experiment with new teaching approaches and to see if they worked for her, especially as she had only a limited experience as a physics teacher. For Ms. Campbell it was important the students were engaged during the lessons (M).

In the first lesson Ms. Campbell told the class the purpose of the lessons was to come to an understanding of what happens in electric circuits. She explained that the focus would not be on formulas and calculations. Instead, students would have to solve conceptual problems, find out how electricity works and what happens inside electric circuits. Student ideas would not be judged as right or wrong, but every idea could be useful and could contribute to get a complete picture of electrical phenomena. Ms. Campbell referred students to the worksheets to read about the way of working during the lessons and about the assessment (O). During the lessons she occasionally repeated she expected students to actively discuss and try to understand the topic. In the group meeting after the second lesson, she concluded some students seemed to actively participate while others were off task most of the time. Ms. Campbell was encouraged to use students' ideas where possible and to avoid giving answers students could find out by themselves. She conducted whole class discussions, but most of the time her students worked in small groups on conceptual problems from the worksheets or on experiments. As in her usual physics lessons she set unfinished problems as homework. The lesson observations of class discussions showed some students participating and coming forward with ideas, while a large part of the class remained off task. After consulting Ms. Campbell, the first author started to assist her in conducting class discussions, and to model aspects questioning, the use of computer simulations and the whiteboard. Ms. Campbell consistently used the particle model as a way to explain the phenomena in electric circuits. Students were observed talking about electric circuits in terms of the particle model. In group meetings the particle model was discussed, first before it was introduced in the classroom and later when issues concerning the model had arisen during the lessons (for example regarding the limits of the model when describing what happens inside a battery; Ms. Campbell remarked that the particle model was incomplete in this respect). Moreover computer simulations and their relation with the particle model were discussed during the group meetings.

In retrospect, Ms. Campbell found it useful to prepare the lessons collaboratively with other physics teachers. Discussing the way of working and the sequence of activities helped her think about her own role during the lessons. She also found it useful to develop the particle model together, because it gave her a clear picture of what was important for the students to understand. Moreover, although in terms of physics content the model was not new for her, it differed from the way electricity was treated in most text books. In the text books she used, electricity was explained in terms of metaphors, such as trucks carrying energy through a circuit, or water flowing through pipes. In Ms. Campbell's opinion the particle model was closer to physical reality than these metaphors and student understanding was fostered by the use of the model in the lessons. She expected it to be of use as a background for students also at a later stage, when they would have to carry out calculations and solve more difficult problems in electricity. In her view the particle model had been used consistently and had been extended on a lesson by lesson basis. In this way the lessons had gradually contributed to the development of student understanding. The regular group meetings during the enactment of the lessons were useful for Ms. Campbell in order to discuss the effectiveness of the approach and the development of student understanding. Moreover, the meetings were useful to get ideas from the other teachers (in particular from Mr. Adler). For example, Ms. Campbell decided to spend a lesson discussing the outcomes of student experiments theoretically, instead of continuing with the next topic (TI).

Looking back at the lessons, Ms. Campbell said she had learned to make students think by themselves instead of providing them with correct answers. She had noticed that during the first lessons students had to get used to the new way of working in class, but later a number of students came forward with their own ideas. This corresponds to the observations made by the first author. In general Ms. Campbell found the students more active in the experimental lessons than in her usual lessons. Students had to think, discuss and carry out experiments before they were given explanations. She said she could manage students working in small groups, but found it difficult to dominate class discussions. In her opinion the parts of the lessons in which students worked independently in small groups had been more effective than the teacher led class discussions (TI).

Four students, interviewed after the lesson, had noticed differences in comparison with their usual physics lessons. Especially they had noticed differences related to the lesson design, namely with respect to the student tasks, the type of problems and the pacing. One girl appreciated that understanding was the main aim of the lessons rather than carrying out calculations. Another girl appreciated the variety of activities and the opportunity to talk with others in whole class activities. Three of the four interviewed students indicated they preferred to work by themselves rather than in groups (SI). The questionnaire showed Ms. Campbell's students did not experience a significantly higher constructivist orientation in the experimental lessons on electricity (N = 20, M = 55.4, SD = 14) as compared to their usual physics lessons (N = 9, M = 51.1, SD = 15) using a related-samples Wilcoxon signed ranks test ($T = 17.5$, $p > 0.05$). The results of this class were affected by the fact that only 9 students from this group completed the questionnaire prior to the lessons.

Ms. Campbell thought the approach of the experimental lessons was generally successful, because the students had obtained good grades in the test for the topic. In her view the approach can be used for other topics as well, but a separate phase of preparation is needed, similar to the preparation of the lessons on electricity. In a follow-up interview a year later, she indicated she made some changes to her lessons as a result of her participation in the intervention. She started asking students for their own ideas when at the beginning of a new topic. She was less inclined to put the theory on the board for students to copy and sometimes used worksheets she prepared herself, instead of the problems from the text book (TI).

CONCLUSIONS AND DISCUSSION

In the previous sections we described the cases of three teachers participating in a professional development process. One of its aims was to collaboratively create inquiry-based instruction as a form of context-based education. Another aim was to help the teachers to develop the knowledge and skills necessary to understand and enact this way of instruction. A number of activities took place in the framework of the professional development process: discussion of the physics content and a particle model, collaborative development of lessons and conjectured learning processes, enactment of the lessons, and reflection. Input to the process was provided based on research literature and on an earlier round of research and coaching took place in the period that the lessons were enacted. Thus, the professional development process had a number of the characteristics of successful professional development interventions listed by Van Veen et al. (2010) and Voogt et al. (2011): subject content and student learning were the starting points of the discussions, teachers' concerns and experiences were integrated in the process, teachers shared experiences and collaborated, classroom coaching was included and the process took a substantial amount of time. We set out to understand how participation in this process gave rise to teacher learning.

Reported Teacher Learning and Changes in Classroom Practice

Topics of the first and second research questions were respectively the learning reported by the teachers and the changes of classroom practice. All three teachers reported new insights with respect to their pedagogical content knowledge (PCK) (Shulman, 1986). For example, Mr. Adler mentioned he had learned to use metaphors on electricity more effectively, Mr. Bradley said he had learned to work with a simple theoretical model of electricity that was gradually extended while student understanding increased, and Ms. Campbell said the model had helped her to get more insight into the aspects of electricity that were important for students to understand. The teachers also reported learning related to the pedagogy used in the classroom. Amongst others, for Mr. Adler this consisted of a realization that teacher explanations were of limited use to promote student understanding and that the group activities during the lessons had increased the student ability to reason about electrical phenomena. Mr. Bradley had gained insight into the possibilities and limitations of using computer simulations and into questioning as a way to promote student thinking. Ms. Campbell had realized the importance of encouraging students to think by themselves and taking student ideas as a starting point. Also changes of attitude were found, such as increased confidence after a second enactment of the lessons (Mr. Adler and Mr. Bradley).

The classroom practice during the experimental lessons had been noticeably different from the teachers' usual lessons and according to the students had moved the classroom culture towards a culture of inquiry (significantly for two of the three teachers). Students indicated they cooperated more with others, carried out more experiments, had more opportunities to investigate things by themselves and had more opportunities to develop their own ideas. We can conclude that changes took place in the teachers' cognitions and attitudes, and in teaching practice, favourable to the creation of context-based lessons. Moreover, changes of classroom practice lasted beyond the time frame of the intervention.

Teacher Learning and Participating in the Professional Development Process

Topic of the third research question was how the reported learning and the teachers' classroom practice are related to participation in the professional development process. The case descriptions show teacher learning was fostered and constrained by the combination of activities, the teachers' contextual situations and their starting point as professional educators. Professional learning in this study took place in various ways and was a dynamic process rather than linear and sequential. This is in line with the *interconnected model of professional growth* proposed by Clarke and Hollingsworth (2002). This model consists of four domains in which change can be initiated. Three domains are part of the everyday professional life of the teacher: a Personal Domain of teacher knowledge, beliefs and attitudes, a Domain of Practice, which refers to teachers experimenting with new approaches and a Domain of consequence in which teachers interpret outcomes. The fourth domain is the External Domain offering support and sources of information. Change initiated in one of the domains can lead to change in other domains through processes of enactment and reflection. The changes take place in a 'change environment' such as the school organization, aspects of which may hinder or facilitate the professional growth process. Clarke and Hollingsworth distinguish short term teacher change resulting from participation in professional development activities and longer lasting 'teacher professional growth'. Voogt et al. (2011) showed the model is also suitable to describe learning processes taking place in teams of teachers who collaboratively designed instruction. We will refer to the interconnected model of professional growth mainly to illustrate the dynamic nature of the teachers' learning processes.

In the following sections we will elaborate on the relation between teacher learning and their participation in the professional development process, using four themes, which were at the core of the intervention: (1) fostering the understanding of theoretical concepts, (2) creating a classroom culture of inquiry, (3) the teachers' concerns, and (4) the reflection and feedback on the enactment of the lessons. Then we will discuss the impact of some factors external to the intervention, in particular the starting point of the teachers prior to the intervention and the situation at their schools.

Fostering the Understanding of Theoretical Concepts

The collaborative discussion of physics content followed by the development and enactment of the lesson series played an important role in the learning process of the teachers. Based on the idea that students need to be provided with theoretical tools to help them talk about phenomena in theoretical terms, rather than as a collection of facts (Kock et al., 2011), we discussed a model of moving charged particles at the level of the students, and ways of using this model to help students overcome conceptual problems. Moreover, we discussed the use of metaphors and various interactive computer simulations and the role of experiments in relation to the particle model. These ideas were not new to Mr. Adler, Mr. Bradley and Ms. Campbell, and they were already aware that understanding electricity in simple direct current circuits is difficult for grade 9 students. However, they indicated that using such a model productively as a theoretical tool in physics instruction in grade 9 was new to them. The discussion and lesson development allowed them to develop a deeper understanding of the physics content in relation to student learning and understanding. There is evidence from research that also for teachers the concepts of electricity are often not without problems (see for example Gunstone, Mulhall, & McKittrick, 2009). Enacting the lessons made the teachers aware of the limits of their own understanding, in particular concerning the limitations of the particle model. For example, students asked questions Mr. Adler and Mr. Bradley were unprepared for, such as how a rechargeable battery works. During their second enactment of the lessons, four to six months after the first, Mr. Adler and Mr. Bradley did not encounter such unexpected situations. This indicates Mr. Adler and Mr. Bradley had learned from the combination of teaching experiment, coaching and continued discussions during collaborative group meetings. In terms of Clarke and Hollingsworth's (2002) Interconnected model of professional growth several domains of teacher change were addressed during the intervention: the intervention started with input from the external domain and personal domains (the theoretical model, the teachers' concerns), while professional development was enhanced by the domain of practice (enactment of instruction) and domain of consequences (interpretations of lesson outcomes). As the changes lasted beyond the time frame of the project, we can talk of professional growth: changes of teacher competences that were more than momentarily.

Classroom Culture of Inquiry

We can discern a similar pattern when considering the changes of classroom interaction and social norms (Cobb & Yackel, 1998), and the creation of a classroom culture of inquiry. Central in the approach were a focus on understanding and explaining, and an interest in student ideas. It was hoped that a classroom culture could be created in which students would actively investigate and try to understand electrical phenomena, through experimental and theoretical tasks. The teacher had to initiate and maintain the change of classroom culture, supported by the available materials (student worksheets, computer simulations). Moreover, the teacher had to orchestrate whole class discussions, work in small groups and individual work. Ideas to change the classroom culture were initiated in the external domain, on the basis of literature and earlier research. The ideas were discussed during the group meetings and where possible incorporated in the design of the lessons. However, to change the classroom culture also a change of teacher behaviour was needed (domain of practice). To some extent this change of behaviour could be included in the lesson planning. For example, as agreed all three teachers started to explain to their classes the new way of working in the experimental lessons, as well as the expectations and the assessment. But to a large extent the teachers had to change their behaviour by responding in new ways to situations that arose during the lessons. For example, instead of explaining physics content, the teachers were expected to encourage students to express their ideas. These changes were fostered by means of modelling and coaching during and after the lessons. Interviews and questionnaires show that the change of the classroom culture was noticeable for the students, although by varying degrees.

Teachers' Concerns

The changes to the lesson content and changes of the classroom culture were initiated in the external domain, but were in line with relevant concerns of Mr. Adler, Mr. Bradley and Ms. Campbell (the personal domain). They were concerned about the limited student understanding and had conjectures of how this could be remedied: for example by using metaphors in a different way or by combining experiments and computer simulations. Some of their conjectures were made the topic of practitioner research projects. They were also interested in deepening their understanding by reading literature on student conceptual problems in electricity and in discussing and trying out suggestions to change their teaching. Mr. Adler and Mr. Bradley decided to repeat the lesson series in the following school year and made modifications to their lessons to make them more successful. We see these as indications that the teachers developed a commitment and co-ownership of the project aims. Thus, the experimental lessons became teaching experiments in which they could test their ideas.

Feedback and Reflection

All three teachers mentioned learning experiences due to the feedback and coaching they received, even though Mr. Bradley and Ms. Campbell received coaching and feedback less frequently than Mr. Adler. Mr. Bradley and Ms. Campbell particularly valued the exchange of ideas and the feedback from the other teachers during the collaborative group meetings. These ideas and feedback most of the time concerned suggestions on how to solve particular classroom situations, for example how to make student groups work more effectively by assigning different roles to students. The coaching, during and after the lessons, was usually related to the lesson content and to what the teachers could do to establish a culture of inquiry, in line with the aims of the lesson series and the teachers' concerns.

All three teachers reflected on the enactment of the lessons and on the way students responded during the lessons and the extent to which expectations were met. These reflections led to new insights related to the teachers' concerns. For example, in this way Mr. Bradley gained insight into the effective use of computer simulations. Reflection on the lessons also led to insights not directly related to the teachers' original concerns. For example, Mr. Adler noticed that in the experimental lessons the level of students understanding was more visible to him. He also noticed the increased understanding of the experimental class in comparison to the non-experimental class. For Mr. Adler this positive feedback served as an incentive that increased his enthusiasm for the project. For Mr. Bradley and Ms. Campbell positive results from the experimental lessons were less evident in the day to day lessons. However, their commitment was high enough to keep experimenting. Mr. Bradley changed aspects of his teaching approach after the first enactment of the lessons, on the basis of his reflections. He felt the response of the class during the second enactment of the lessons was more successful than when he tried it for the first time. Reflecting on her lessons, Ms. Campbell gained insight into ways to foster students' active thinking and into instructional methods that suit her (such as group work) and those that don't (such as whole class discussions).

Coaching and feedback made it possible to address the teachers' needs at an individual level. This is in line with Fullan (1985) who argues that, besides practice, feedback is essential when teachers learn new skills, because this learning is an incremental and developmental process. Continued practice, coaching, reflection and collaborative discussions helped sustain the teachers' developments.

The Teachers' Starting Points and Contextual Situations

Mr. Adler, Mr. Bradley and Ms. Campbell reported different learning experiences and were not equally successful in moving their teaching practice towards context-based education. This can be understood at least partly from their starting points as teachers and from the contextual situation (the change environment) in which they worked. Although in all three cases the classroom culture changed in the experimental lessons, the largest effect was seen in Mr. Adler's class, followed by Mr. Bradley's. Prior to the intervention, students in Mr. Adler's class already were used to coming forward with their questions and ideas. In combination with his long experience as a teacher and his resolve to include all students, this can help us understand why the culture in Mr. Adler's classroom changed the most. On the other hand, the classroom management required for the new pedagogy was difficult to handle for Ms. Campbell, who was only in her second year as a physics teacher.

Another factor likely to have influenced teacher learning and the changes of teacher practice, is the frequency of feedback and reflection meetings. Mr. Adler received feedback more often than Mr. Bradley and Ms. Campbell and adaptations to his lessons could be made more frequently. On the other hand, Mr. Bradley and Ms. Campbell started their lessons later and could use some of the experience already gained during the first enactment. Although it is difficult to determine the impact of this difference, lesson by lesson evaluations were an important aspect of the approach and in this respect the conditions for Mr. Bradley and Ms. Campbell were not optimal.

Contextual factors played a role in the effect of the intervention on the longer term. Mr. Adler and Mr. Bradley had the possibility to repeat the lesson series the next school year and decided to do so, which gave rise to new learning experiences. The opportunity of teaching the lesson series a second time was not available to Ms. Campbell as she did not teach a grade 9 class the following school year. However, Ms. Campbell decided to make changes to her general physics teaching practice based on what she had learned. Colleagues of Mr. Adler and Mr. Bradley responded in different ways to the experimental lessons. Mr. Adler's colleagues asked for advice on how to improve students' understanding on electricity, while Mr. Bradley's colleagues questioned aspects of the experimental lessons. The examples illustrate that on the one hand the points of departure of the teachers and on the other hand the context in which the professional development took place, afforded and constrained the results that could be obtained.

Coda

The intervention described in this chapter appears effective in changing the knowledge and practice of teachers, towards a more context-based approach. It can be seen as a paradigm case illustrating the underlying mechanisms of this type of interventions. The driving force behind the professional development process is the teachers' willingness to invest in changing their teaching practice, in order to obtain better results in terms of student understanding and active inquiry. There are two important prerequisites for this process to start and continue. The first prerequisite is for the teachers to believe that a new instructional approach could work. An agenda for educational innovation matching with classroom concerns of the participants can foster this belief. Moreover, the teachers then have a real interest in the results of the innovative lessons and are likely to develop interest and commitment. The second prerequisite is for the teachers to have the means at their disposal to have a fighting chance in the classroom. They will have to be helped with research-based ideas to develop innovative education. A local instruction theory has the potential to provide such ideas, while general guidelines on context-based education are not domain specific and detailed enough (Leach & Scott, 2008). Earlier research already showed the importance of a well-balanced local instruction theory (Kock et al., 2011).

As the different activities of the intervention complemented each other, it is comprehensible that change became apparent in various domains of Clarke and Hollingsworth's Interconnected model of professional growth (2002). During the initial discussions on lesson content and pedagogy, and during the collaborative design of instruction there was input from educational research, but also room for the teachers to raise their own classroom concerns. This opened the possibility to provide coaching on an individual basis and to reflect on issues that really mattered to the participants, while keeping a focus on the local instruction theory and the chosen pedagogy. The enactment of the lessons in combination with classroom coaching made the teachers realize the consequences of the chosen approach in practice. Feedback and reflection gave new insights and led to modifications of the local instruction theory and the instructional materials.

The teachers experienced success when they noticed increased student participation and understanding. These experiences amplified commitment and interest. Through these experiences the teachers' learning processes are more likely to become self-sustaining and to lead to lasting changes of teaching practices towards a more context-based approach. However, all three teachers also experienced some setbacks and less successful activities. The cases of Mr. Bradley and Ms. Campbell show that a noticeable increase of student participation and understanding is not always easy to accomplish. Coaching, feedback and the possibility to exchange experiences appeared to help teachers persist in the light of less successful experiences.

The study concerned an intervention with a specific purpose and setting, and only three participants. Obviously, it cannot be taken as a blueprint to be used directly in interventions at a larger scale. Moreover, the results indicate particular modifications to the intervention could increase its effectiveness. First, feedback and reflection are probably most effective on a lesson by lesson basis, as in the case of Mr. Adler. Mr. Bradley and Ms. Campbell might have been more successful if they had received more frequent feedback. In the planning of similar interventions, lesson by lesson feedback and reflection has to be an important consideration. Next, research findings indicate professional development interventions are more successful when teams of teachers at a school are involved (Van Veen et al., 2010), whereas the teachers in this study cooperated without the involvement of colleagues at their schools. Mr. Bradley's colleagues were somewhat sceptical about the experimental lessons. Without support it might be difficult for him to further develop the approach and sustain his learning process. A similar intervention in collaboration with a team at a school would have a different dynamic and could be a topic of further study. Finally, in this study we developed a local instruction theory and a prototype of a lesson series, which need further optimization. The teachers mentioned areas of improvement, such as the wording of certain tasks, the balance between student freedom and structure, and the inclusion of specific tasks to support student work with computer simulations.

NOTES

[1] The words 'science' and 'science education' potentially refer to all scientific domains. However, in the context of this chapter these words refer to the natural sciences generally taught at secondary school level: chemistry, biology and physics.

[2] The interactive simulations illustrated aspects of a simple charged particle model, but not a single simulation illustrated the entire model. For example, one interactive simulation illustrated the attraction and repulsion between electric charges, others illustrated the flow of electric current or the voltage across a battery. We considered it important for the teachers to understand in detail what could and what could not be illustrated by each of the interactive simulations.

[3] All names are pseudonyms.

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10. ANALYSING MIDDLE SCHOOL STUDENTS' PERCEPTIONS OF THEIR SCIENCE CLASSROOM IN RELATION TO ATTITUDES AND MOTIVATION

INTRODUCTION

In recent years, education has been blamed for graduates not being sufficiently able to apply their knowledge to solve complex problems in working contexts. Therefore, the development and implementation of instructional practices that foster students' skills to communicate, think and reason effectively, make judgements about the accuracy of information, solve complex problems and work collaboratively in diverse teams, remains an important challenge for today's education (Pellegrino, Chodowsky, & Glaser, 2001). Parallel to these, educators need a new perspective, educational goals have changed and memorization of facts has been accepted to be less important than problem-solving skills and life-long learning. On top of this, a decline in positive attitudes towards science has been found in many studies and Turkey is not an exception (Catsambis, 1995; Weinburgh, 1994; Hassan, 2008; Jung & Reid, 2009; Kozcu-Cakir, Senler, & Gocmen-Taskin, 2007). At present, theoretical and empirical studies in education favour the construction of knowledge model over the traditional information transmission model (Yarger, Thomas, Boysen, & Marlino, 1999). According to constructivist theory, individuals construct knowledge in interaction with their environment and in this process both the individual and the environment are changed (Abdal-Haqq, 1998; Richardson, 1997). Constructivism has become a leading theoretical position in science education (Tobin, 1993). Recently, the principles of the constructivist approach have been widely applied in education especially in science, mathematics and primary school education and have shaped and become visible in classrooms (Kesal, 2003). New learning environments based on constructivist theory claim to develop an educational setting to reach this goal, making students learn the core issue and defining instruction as enhancing learning (Lea, Stephenson, & Troy, 2003). Constructivist learning environments promote adaptive motivational beliefs by offering opportunities to develop autonomy, responsibility and optimal level of challenge (Ames, 1992). In a student-centred learning environment, learners are given actual control and self-direction of academic tasks through task and assessment design that enhance motivational effects. There is sufficient evidence of the importance of considering the motivational dimensions

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of learning activities and environments. Learners' capacity to engage in deep and generative learning is closely linked to efficacy beliefs, motivational states and levels of confidence (McLoughlin & Luca, 2004).

Context-based learning environments and constructivist learning environments are closely related from a theoretical perspective. In practice, context-based learning environments often show various constructivist elements like personal relevance and shared control. Context-based approaches can be defined as "approaches adopted in science teaching where contexts and applications of science are used as the starting point for the development of scientific ideas" (Bennett, Lubben, & Hogarth, 2007). Like in all constructivist learning environments, a key element of a context-based learning environment is active learning (Gilbert, 2006; Parchmann et al., 2006). According to De Putter, Taconis and Jochems (2012), shared control and personal relevance and the approach towards knowledge of something that has to be constructed and hence is uncertain to some extent, are key elements of context-based learning environments.

In learning environments research, attitude is also the one of the factors which affects a learning environment. As defined in Newhouse's (1990) study, it is a positive or negative feeling about a person, object or issue. These feelings are affected by personal opinions and these personal opinions can be gained by personal life experiences and education. Moreover, current studies in the field of educational psychology, science education, and learning environment have also emphasized the importance of the relations between students' learning environment and their motivation (Ben Ari, 2003; Kaplan & Middleton, 2002; Manning, 2000; Stipek, 2002).

With the curriculum changes in Turkey (National Ministry of Education, 2006), a constructivist view of learning have become more popular and students' active involvement in the learning process, their experiences and prior knowledge, social collaboration in educational settings to construct their knowledge receive more attention. All these changes have drawn researchers' attention and new classroom learning environment have become subject to research.

In reaction to the importance of fostering science education in Turkey and in the frame of the research outcomes mentioned so far, this chapter examines the relationships of the constructivist characteristics of (context-based) learning environment to students' attitude and motivation.

THEORETICAL BACKGROUND

Constructivism is a learning theory that recognizes the importance of considering students' perceptions of the classroom learning environment and has had a major influence on science education in the past two decades (Cannella & Reiff, 1994 cited in Abdal-Haqq, 1998). A constructivist learning environment encourages students to think of complex problems, to construct on their own ideas and to solve the problem. These problems may be taken from every-day-life or derived from scientific practice and may be positioned within 'a context'. Teachers develop a situation for their students to explain and select a process for grouping materials, while building a bridge between what students already know and what they want them to learn. This is why teacher consideration of student perceptions about the learning environment is a significant element in improving the teaching and learning environment when designing viable conceptual constructs for their students (e.g. Jonassen, 1998). Research has focused on different aspects of constructivist learning environments, for example, some research has focused on the perceptions of students about their science classrooms, some has been related to the practical application of constructivism in the learning environment and some has examined constructivism-oriented curricula. Learning environments research has studied those associations in different types of classroom environments, for instance science laboratory classroom environments, computer-assisted instruction classrooms, constructivist classroom environments and cross-national studies of science classroom environments (Fraser, 2002). It has also been used to map context-based learning environments (De Putter et al., 2012).

Particularly, the questionnaire entitled the *Constructivist Learning Environment Survey (CLES)* was developed to assess the degree to which constructivist teaching and learning approaches are established in the classroom learning environment. The first version of the questionnaire with 58 items ranging from 9 to 20 items in scales was introduced in 1991 (Taylor & Fraser, 1991). Later, a revised version of the CLES was constructed with 30 items. The scales in the CLES (Personal Relevance, Shared Control, Critical Voice, Student Negotiation and Uncertainty – see Table 1 for descriptions) represent the key dimensions of critical constructivism (Taylor, Fraser, & Fisher, 1997). The CLES has been used in studies of high school science and mathematics classrooms (Dryden & Fraser, 1998) and validated and used in various studies in different countries (e.g. Stolarchuk & Fisher, 2001). Johnson and McClure (2004) shortened and revised the CLES to 20 items (four items for each dimension). This shortened and revised version of the CLES was translated and adapted into Turkish by Yılmaz, Cakiroglu and Boone (2006). In a recent study in Turkey, the CLES was adapted and validated for pre-service teachers (Aydin, Boz, Sungur, & Cetin, 2012).

Attitude towards science is defined as the feelings, beliefs and values held about the enterprise of school science, science and the impact of science on society (Osbourne, Simon, & Collins, 2003). There is a large volume of published studies describing the importance of attitudes in science education and give evidence to its influence on behaviors, supporting scientific inquiry and achievement (e.g. Kaballa & Crowley, 1985). Many research projects have indicated that attitudes influence achievement, rather than achievement influencing attitudes (Schibeci & Riley, 1986). Students with positive attitudes towards science tend to have higher scores on achievement measures (Oliver & Simpson, 1988; Weinburgh, 1994). Moreover, several studies have pointed towards the influence of classroom environment as a significant determinant of attitude (Piburn & Baker, 1993; Talton & Simpson, 1987; Lyons, 2006). More specifically, in science learning environments, studies have generally shown that the classroom learning environment is a strong factor in determining and predicting students' attitudes toward science (Aldolphe, Fraser, & Aldridge, 2003; Telli, Cakiroglu, & den Brok, 2006). According to the result of this research, the learning environment is positively and significantly related to students' attitudes.

Many researchers have shown that the classroom environment has a great influence on students' *motivation* in terms of expectancy beliefs, task value belief, and goal orientations (Ames, 1992; Greene, Miller, Crowson, Duke, & Akey 2004; Stefanou, Perencevich, DiCintio, & Turner, 2004). According to Ames (1992), there are six classroom structures which are manipulable and have impact on these motivational variables: task, authority, recognition, grouping, evaluation and time. It was suggested that in order to promote mastery goal orientation, effective strategy use, active engagement, intrinsic interest and attributions to effort, there should be novelty and variety in tasks. In addition, tasks should provide students with an optimal level of challenge and help students set short-term goals and focus on the meaningful aspects of activities. 'Contexts' may provide such meaning. Moreover, classroom structures should encourage student autonomy and responsibility in the learning process. Students should be able to make choices and feel that they have control over their learning. Furthermore, it is suggested that classroom structures emphasizing individual improvement and mastery and providing opportunities for improvement foster adaptive motivational beliefs. In fact, in an empirical study conducted by Müller and Louw (2004), it was found that students' interest, intrinsic motivation, and self-determined forms of extrinsic motivation were related to perceived support of autonomy and competence, relevance of the contents and transparency of requirements. These conditions can be found in constructivist learning environments where students have an active role in their learning. Moreover, Greene et al. (2004) demonstrated that student perceptions of classroom environment in terms of motivating tasks, autonomy support and mastery evaluations are in association with their motivation. More specifically, it was found that the perception of the tasks as important, relevant, and interesting is related to high self-efficacy, high mastery goal orientation, and perception that the task is instrumental to future success. In line with these findings, the authors of this study proposed that learning environments in which students are autonomous in their learning, receive informative feedback concerning their progress, experience a friendly and positive atmosphere and interact with each other during the learning process are likely to promote intrinsic motivation. In a context-based learning environment, the context would provide meaning and relevance.

In sum, these results provide further evidence for contextual effects on achievement motivation (e.g., Ames & Archer, 1988; Solmon, 1996) by showing that classrooms are settings with qualities that can transcend the personal qualities of the students and that the teaching strategy implemented in the classroom – and to which the students are exposed – defines the characteristics of the classroom setting. The results also support that gender difference is an important factor in the classroom setting that influences the learning environment, attitudes towards science and motivation of students. On the basis of these, the following research questions are aimed to be investigated in the study:

1. What is the relationship between elementary school students' perceptions of science classroom environment from a constructivist perspective and their attitude towards science?
2. What is the relationship between elementary school students' perceptions of the science classroom environment from a constructivist perspective and their adaptive motivational beliefs (intrinsic goal orientation, task value, control of learning beliefs and self-efficacy for learning and performance)?
3. Are there any significant differences between 8th grade boys and girls with respect to their perceptions of the science learning environment from a constructivist perspective, adaptive motivational beliefs and attitude towards science?

METHOD

Sample

Fifteen schools in Ankara, Turkey were involved, including 956 randomly selected students (462 girls, 493 boys and one student did not indicate gender) in 36 eighth grade classrooms. Schools were selected randomly. Class size in these schools varied from 20 to 40 students.

Instruments

Three questionnaires were administrated to the students in the overall study: the Constructivist Learning Environment Survey (CLES), Test of Science Related Attitude (TOSRA) and Motivated Strategies for Learning Questionnaire (MSLQ).

The first questionnaire, the CLES, was used to obtain measures of students' perceptions of the frequency of occurrence of five key dimensions of a constructivist learning environment. High scores on these dimensions are typical for a constructivist learning environment. The CLES was originally developed by Taylor and Fraser (1991) and contains 30 items. Johnson and McClure (2004) shortened and revised this version of the CLES to 20 items (four items for each dimension) with a five-point Likert-type response scale with the following alternatives: (1) Almost Always, (2) Often, (3) Sometimes, (4) Seldom, (5) Almost Never. This shortened and revised version of the CLES was translated and adapted into Turkish by Yılmaz, Cakiroglu and Boone (2006). Table 1 gives information about the sub dimensions of the CLES and alpha reliability at an individual level. The alpha coefficient indicated how well the scales measure what it is intended to measure. A value of .7 is sufficient.

Table 1. Scales, scale descriptions, sample items and alpha reliability for the CLES

Scales	*Scale description*	*Sample Item*	*Alpha reliability*
Personal Relevance (PR)	Extent to which teachers relate science to students' out-of-school experiences.	In this science class, I learn about the world outside the school.	0.75
Student Negotiation (SN)	Extent to which opportunities exist for students to explain and justify to other students their newly developing ideas and to listen and reflect on the viability of other students' ideas.	In this science class, I ask other students to explain their ideas.	0.68
Shared Control (SC)	Extent to which students are invited to share control of the learning environment with the teacher, including the articulation of their own learning goals, design and management of their learning activities and determining and applying assessment criteria.	In this science class, I help the teacher to plan what I'm going to learn.	0.72
Critical Voice (CV)	Extent to which a social climate has been established in which students feel that it is legitimate and beneficial to question the teacher's pedagogical plans and methods to express concerns about any impediments to their learning.	In this science class, it's OK to ask the teacher, 'Why do we have to do this?'	0.69
Uncertainty (U)	Extent to which opportunities are provided for students to experience scientific knowledge as arising from theory dependent inquiry, involving human experience and values, evolving and non-foundational, culturally and socially determined.	In this science class I learn that the views of science have changed over time.	0.58

Source: Taylor and Fraser (1991)

The second questionnaire, Test of Science Related Attitude (TOSRA) was used to measure students' attitudes towards science. Based on Klopfer's (1976) six categories of conceptually different attitudinals, Fraser (1981) developed this questionnaire. Originally, it consisted of 7 scales: social implications of science, normality of scientists, attitude to scientific inquiry, adaptation of scientific attitudes, enjoyment of science lessons, leisure interest in science, and career interest in science. Each of the seven scales included 10 items. The TOSRA items are scored on a 5-point scale, ranging from strongly agree (5) to strongly disagree (1). The TOSRA has been widely used in previous studies in Western and non-Western countries and has a high degree of reliability and validity (Fraser, 2002). The questionnaire was first translated into Turkish by Telli, Cakiroglu and Rakici (2003). In the present study, based on the research questions, only four scales from the original form of TOSRA were selected. These are adaptation to science attitudes, enjoyment of science lessons, leisure interest in science and career interest in science. Table 2 gives information about the four subscales of the TOSRA and alpha reliability for the present study.

Table 2. Scales, scale descriptions and sample items for the TOSRA

Scales	*Scale description*	*Item Sample*	*Alpha reliability*
(A) Adaptation to science attitude	Adoption of 'scientific attitudes'	I am curious about the world in which we live (+)	0.64
(E) Enjoyment of science lessons	Enjoyment of science learning experiences	I dislike science lessons (–)	0.85
(L) Leisure interest in science	Development of interest in science and science related activities	I would like to belong to a science club (+)	0.82
(C) Career interest in science	Development of interest in pursuing a career in science	I would dislike being a scientist after I leave school (–)	0.78

Source: Adapted from Fraser (1981)

The third questionnaire, the Motivation Strategies for Learning Questionnaire (MSLQ) developed by Pintrich, Smith, Garcia and McKeachie (1991) was used to measure students' motivational beliefs. The MSLQ is a self-report instrument with two main sections: a motivation section and a learning strategies section. The motivation section consists of 31 items in six subscales while the learning strategies section consists of 50 items in nine subscales. The Turkish version of the MSLQ was translated and adapted into Turkish by Sungur (2004). For the present study, four subscales in the motivation section (intrinsic goal orientation, task value, control of learning beliefs and self-efficacy for learning and performance) were used to measure students' adaptive motivational beliefs, such as self-efficacy, task value, and mastery goals. Table 3 gives information about the four subscales of the MSLQ and alpha reliability for this study.

Analysis

The statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS). The data obtained in the study were analysed using descriptive statistics and inferential statistics.

Table 3. Scales, scale descriptions and sample items for the MSLQ

Scales	*Scale description*	*Sample Item*	*Alpha reliability*
(IGO) Intrinsic Goal Orientation	A desire to improve one's ability, master a skill and understand the learning material	The most satisfying thing for me in the science lesson is trying to understand the contents as thoroughly as possible.	0.71
(TV)Task Value	Judgements of how interesting, useful, and important the course content is to the student	It is important for me to understand the subjects in science lessons.	0.80
(CB) Control of Learning Beliefs	Beliefs about the causes of success and failure and how much perceived control one has to bring about outcomes or to control one's behaviour	If I cannot learn the subjects in science lessons, this is my own fault.	0.65
(SE) Self-Efficacy for Learning and Performance	One's beliefs about one's own ability to perform a specific behaviour	I expect that I will be very successful in science lessons.	0.83

Source: Pintrich, Smith, Garcia and McKeachie (1991)

There were four variables in this study. The three variables were elementary school students' perceptions of their science classroom environment from a constructivist learning environment perspective (personal relevance, uncertainty, critical voice, shared control, and social negotiation), students' attitudes towards science (adaptation of science attitudes, enjoyment of science lesson, leisure interest in science and career interest in science), and their adaptive motivational beliefs (intrinsic goal orientation, task value, control of learning beliefs and self-efficacy). These variables were continuous. The last variable was students' gender, which was a discrete and nominal scale of measurement. It was used to create and compare two groups of student.

The research questions were addressed using canonical correlation analysis. Canonical correlation indicated the 'overall' correlation between two groups of interrelated variables (Sherry & Henson, 2005). The size of values are interpreted like 'ordinary' correlation coefficients; values below .4 indicate a weak relationship (if significant), values in between .4 and .7 indicate a moderate relationship, and values over .7 indicate a strong relationship. Coefficients indicate the rate of change in standard deviations in the dependent variable when the independent variable changes by one standard deviation.

To answer the first question, the canonical correlation between the set of constructivist learning environment variables and the set of attitude towards science variables. In order to address the second research question, a canonical correlation analysis was performed between the set of science constructivist learning environment and set of adaptive motivational beliefs. For the third question, three separate MANOVAs were conducted with three groups of dependent variables (constructivist learning environment scales, adaptive motivational belief scales and attitude scale) each using one independent variable (students' gender). Hence, for each of the three groups of dependent variables, it was tested whether or not there were any gender related differences in the values of the dependent variables.

In addition to the canonical correlation analysis, we looked for specific correlation between individual CLES-variables on one hand, and the variables within the TOSRA and MSLQ group on the other.

RESULTS

The results of the statistical analysis for the first question are presented in Table 4. The first canonical correlation was 0.65 (42 % overlapping variance), accounting for the significant relationships between the set of science constructivist learning environment variables and the set of adaptive motivational beliefs. The remaining canonical correlations were effectively zero. With a cut-off correlation of .30, the first pair of canonical variates indicated that all constructivist learning environment variables and attitude variables were positively related with each other. In other

Table 4a. Correlations, standardised canonical coefficients, canonical correlations, between constructivist learning environment variables and attitude variables

	Attitude Variables	
Constructivist Learning Environment Variables	*Correlation**	*Coefficient***
Personal Relevance (PR)	.92	.58
Uncertainty (U)	.68	–.06
Critical Voice (CV)	.90	.43
Shared Control (SC)	.62	.13
Social Negotiation (SN)	.65	.06
Attitude variables		
Adaptation to Science Attitudes (A)	.79	.21
Enjoyment of Science Lessons (E)	.96	.50
Leisure Interest in Science (L)	.90	.33
Career Interest in Science (C)	.81	.08
Canonical Correlation	.65	

* *with a cut-off correlation of 0.30 (Tabachnick & Fidell, 1996)*
** $p < 0.05$

Table 4b. Correlations, standardised canonical coefficients, canonical correlations, between constructivist learning environment variables and motivational belief variables

	Motivational belief variables	
Constructivist Learning Environment Variables	*Correlation**	*Coefficient***
Personal Relevance (PR)	.91	.52
Uncertainty (U)	.75	.12
Critical Voice (CV)	.89	.42
Shared Control (SC)	.61	.05
Social Negotiation (SN)	.66	.05
Motivational Belief Variables		
Intrinsic Goal Orientation (IGO)	.89	.28
Task Value (TV)	.95	.55
Control of Learning Beliefs (CB)	.77	.11
Self-Efficacy for Learning and Performance (SE)	.80	.18
Canonical Correlation	.65	

* *with a cut-off correlation of 0.30 (Tabachnick & Fidell, 1996)*
** *$p < 0.05$*

words, perceptions of higher levels of personal relevance, uncertainty, critical voice, shared control and social negotiation in a classroom environment were associated with higher levels of adaptation to science attitudes, enjoyment of science lessons, leisure interest in science and career interest in science.

A second canonical correlation analysis was conducted to examine the relationship between the set of constructivist learning environment variables and the set of motivational belief variables. The second canonical correlation was 0.65 (42 % overlapping variance). With a cut-off correlation of .30, the first canonical variates indicated that all constructivist learning environment variables and motivational belief variables were positively related with each other (Tables 4a and 4b). The results obtained from the analysis of the second research question revealed that perceptions of higher levels of personal relevance, uncertainty, critical voice, shared control and social negotiation in a classroom environment were associated with higher levels of intrinsic goal orientation, task value, control of learning beliefs and self-efficacy for learning and performance.

For the third question, three separate MANOVAs were conducted with three groups of dependent variables (constructivist learning environment scales, adaptive motivational belief scales and attitude scale) each using one group of independent variable (students' gender). Results are presented in Table 5.

The first MANOVA was run over five dependent variables (PR, U, CV, SC and SN), which were subscales of a constructivist learning environment, and

Table 5. Test of gender differences of the constructivist learning environment pattern

*Constructivist learning environment pattern**	*df*	*Error df*	*F*	*p*	*Partial eta squared*	*Observed power*
PR	1	832	15.53	.000	.018	.976
U	1	832	2.63	.105	.003	.367
CV	1	832	11.36	.001	.013	.920
SC	1	832	.898	.344	.001	.157
SN	1	832	4.93	.027	.006	.602
Motivation Pattern						
IGO	1	841	16.94	.000	.020	.984
CB	1	841	21.44	.000	.025	.996
TV	1	841	14.84	.000	.017	.970
SE	1	841	4.61	.032	.005	.574
Attitude Pattern						
A	1	751	28.93	.000	.037	1.00
E	1	751	13.89	.000	.018	.961
L	1	751	19.25	.000	.025	.992
C	1	751	14.79	.000	.019	.970

Abbreviations used:
* *PR (Personal Relevance), U (Uncertainty), CV (Critical Voice), SC (Shared Control), SN (Student Negotiation)*
* *IGO (Intrinsic Goal Orientation), TV (Task Value), CB (Control of Learning Beliefs) SE (Self-Efficacy for Learning and Performance)*
* *A (Adaptation to Science Attitudes), E (Enjoyment of Science Lessons), L (Leisure Interest in Science), C (Career Interest in Science)*

one independent variable: gender. There was a significant difference between boys and girls on the combined dependent variables of the constructivist learning environment subscales ($F(5, 828) = 3.98$, $p < .001$). When the results for the dependent variables were considered separately, the only two differences reaching statistical significance, using a Bonferroni adjusted alpha level of .01, were PR and CV (see Table 5). An inspection of the mean scores indicated that females reported slightly higher levels of PR (M = 14.40, SD = 3.6) than males (M = 13.40, SD = 3.7). For the CV an inspection of the mean scores indicate that females have higher levels of CV (M = 13.94, SD = 3.49) than males (M = 13.10, SD = 3.68). Therefore, the results, as shown in Table 5, indicate that girls have more personal relevance (PR) and critical voice (CV) than boys.

In the second MANOVA, four dependent variables (IGO, TV, CB, SE), which were subscales of the motivational belief variable, and one independent categorical variable, gender, were used. There was a statistical difference between girls and boys on the combined subscales of adaptive motivational beliefs (*F*(4, 838) = 6.3, *p* < .001) When the results for the dependent variables were considered separately, the differences that reached statistical significance using a Bonferroni adjusted alpha level of .0125. The analysis showed that girls have higher levels of intrinsic goal orientation (IGO), control of learning belief (CB) and task value (TV) than boys (see Table 5).

The third MANOVA was performed over four dependent variables (A, E, L and C) which were subscales of the attitude variable and one independent variable, gender. It was found that there was a significant difference between boys and girls on the combined dependent variables (*F*(4, 748) = 7.9, *p* < .001). When the results for the dependent variables were considered separately, all variables reached statistical difference using a Bonferroni adjusted alpha level of .0125. The analysis showed that girls had higher levels of adaptation to science attitudes, enjoyment of science lessons, leisure interest in science and career interest in science than boys (see Table 5).

CONCLUSIONS AND DISCUSSIONS

The present study was designed to examine the relationship between elementary school students' perception of the science classroom environment from a constructivist perspective, their adaptive motivational beliefs and their attitude toward science. Moreover, it examined the effects of gender differences on the perceived classroom learning environment, motivation and attitude towards science.

First, findings pointed out that the perception of higher levels of personal relevance, uncertainty, critical voice, shared control and social negotiation in a classroom environment were associated with higher levels of adaptation to science attitudes, enjoyment of science lessons, leisure interest in science and career interest in science. This means that constructivist learning environment variables and attitude variables were positively related to each other. These results are consistent with those of other studies (e.g. Puacharean & Fisher, 2004; Fisher & Kim, 1999). For example, in a study carried out by Fisher and Kim (1999) the effect of a science curriculum reform was examined. Participants were Grade 10 and Grade 11 students. They were administered the CLES and TOSRA. Their study showed a statistically significant correlation between their attitudes and scales of personal relevance, shared control and student negotiation for grade 10 and for the scales of personal relevance, uncertainty and shared control for grade 11. They also found that subscales of the constructivist learning environment were positively related to the subscales of attitude toward science. Hence, we conclude that if students' perceive their science learning environment as more constructivistic, their attitude towards science is also more positive.

Second, all constructivist learning environment variables and all adaptive motivational belief variables were found to be positively related with each other. This means that perceptions of higher levels of personal relevance, uncertainty, critical voice, shared control, social and social negotiation in a classroom environment were associated with higher levels of intrinsic goal orientation, task value, control of learning beliefs and self-efficacy for learning and performance. A strong relationship between a constructivist learning environment and motivation has also been reported in literature. For example, Kim (2005) showed that a constructivist learning environment has positive effects on the motivation of students; it increases the self-efficacy of students. Furthermore, Ben-Ari (2003) found a positive relationship between the classroom learning environment and motivation. According to Ben-Ari, when students perceived the classroom as having more mastery goal structure, they had higher adaptive motivational beliefs. Additionally, Fosnot (1996) reported that classroom environments emphasizing constructivism and group work techniques led students to feel more autonomous in their learning and fostered their intrinsic motivation, competence, and self-esteem. Supporting these findings, Johnson and Johnson (1991) stated that in constructivist classroom environments students tend to show greater commitment to learning; they do not avoid difficult tasks and they persist longer in order to successfully complete the tasks. Hence, our conclusions are consistent with previous research.

Considering the effect of gender, there are some differences between the results of the current study and of previous studies, especially as regards the attitude variable. A large and growing body of literature has indicated that boys' attitude towards science are more positive than girls' (Catsambis, 1995; Jones, Howe, & Rua, 2000; Piburn & Baker, 1993; Greenfield, 1996). Contrary to expectations, in the current study girls' attitudes towards science were found to be more positive than those of boys', which supported some previous studies in Turkey (Cavas, Cavas, Tekkaya, Cakiroglu, & Kesercioglu, 2009). For example, Telli, Cakiroglu and den Brok (2006) found a significant gender difference in career interest in science, but no significant difference in the enjoyment in science and leisure interest concerning science. When the careers of university professors in Turkey are examined, a high proportion of female professors can be found at the universities compared to Western Europe and the United States (Ozbilgin & Healy, 2001). That is why girls in Turkey might have more role models of female scientists which could be a reason for their higher levels of positive attitudes towards science and their self-confidence. On the other hand, Schibeci and Riley (1986) and Jones et al. (2000) emphasized that girls' attitudes towards biology were more positive than those of boys, while boys' attitudes towards physical science were more positive than those of girls. The Turkish elementary science curriculum is a combined curriculum of physics, chemistry and biology. Biological science subjects are mainly taught in grade 8 in the spring months, which overlapped with the implementation of this study.

In general, the studies related to constructivist learning environments have not focussed on gender differences. Yet, some studies related to learning environments, such as those by Huang (2003) and Rakici (2004) have shown that girls perceived their learning environment as more constructivistic than boys. In this respect, the results of the current study are similar to those results in that they have shown that girls' mean scores are higher than those of boys.

With regard to gender effects on motivation, while some of the previous studies support the results of the present study (Schibeci & Riley, 1986; Jones et al., 2000), others do not. According to the results of the current study, girls reported a stronger intrinsic goal orientation, control of learning beliefs and task value beliefs than boys. The self-efficacy dimension did not show statistically significant differences between both genders for this research. Some research in the literature emphasizes that girls are more motivated in the art and language subjects, whereas boys are more motivated in science and mathematics subjects; yet, the study of Yavuz, (2006) conducted in Turkey, showed that girls had higher motivational traits than boys in all grades of elementary science classes. Another study conducted in Turkey similarly has shown that girls' higher mean scores of the learning environment are more related to intrinsic goal orientation than boys (Özkan, 2003). Similarly, some previous studies have also indicated that girls' self-efficacy mean scores are higher than those of boys (Pajares, Miller, & Johnson, 1999; Pajares, Britner, & Valiante, 2000).

To sum up, a (positively perceived) constructivist learning environment is one of the factors positively related to students' motivation and their attitude towards science. Moreover, this study suggests that gender has a significant effect on how the learning environment is perceived, their motivation and their attitude towards science, all in favour of girls. Although there are some differences between the results of the present study and previous studies, in general the findings of this study are parallel to those in the literature.

The current study stresses the importance of implementing the various constructivist characteristics in context-based education to help improving students' science motivation and attitudes. Additionally, our study stresses the relevance of gender differences when creating context-based or other constructivist learning environments. The finding from this study that girls' attitudes towards science and their motivational beliefs towards science subjects are higher than those of boys seems important, but it is not yet clear what this implies. Cultural differences might play a role in this. Further research is also advised with respect to different grade levels. Also involving the context-related aspects of context-based education more explicitly may be helpful in understanding how such elements affect students' perceptions and factors that play a role in this, such as gender.

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11. A FRAMEWORK FOR EMPOWERING TEACHERS FOR TEACHING AND DESIGNING CONTEXT-BASED CHEMISTRY EDUCATION

INTRODUCTION

Context-based curricula are now becoming more widely used in upper secondary chemistry education because they might solve problems experienced with the traditional, concept-based curricula (Pilot & Bulte, 2006; Smith, 2011). Context-based innovation has large implications for teaching chemistry. Instead of teaching by transmitting content knowledge, the focus in teaching will be on coaching and enabling students to learn chemistry meaningfully using related contexts and concepts. As a consequence, teachers will be asked to pay more attention to the relation between chemistry and societal or personal issues, aspects of chemistry they usually ignore, or do not feel very comfortable with (Coenders, Terlouw, & Dijkstra, 2008). For a successful implementation of such a new pedagogy professional development (PD) is required.

Teachers are considered the most important agents in shaping a new curriculum and bringing about change in educational practices. However, during educational innovations teachers often only execute innovative ideas and materials of others (policy makers, curriculum designers, researchers), resulting in the innovation not being adopted by teachers in the manner intended or changes in the teachers' cognitions or behaviour that did not persist (Van Driel, Meirink, Van Veen, & Zwart, 2013). For a successful and enduring curriculum innovation, researchers and policy makers increasingly advocate having teachers to participate in the design of innovative teaching materials (Parchmann & Luecken, 2010; Bulte & Seller, 2010). Giving teachers the role of designer will reduce the feeling among teachers of being forced to change their practices and can avoid incongruence of what is intended and what occurs in the classroom practice. Furthermore, by designing new teaching materials, teachers can gain commitment and ownership with respect to the innovation, and enable a substantial change in their knowledge, skills, beliefs and attitudes about the innovation (see also chapter 8 by Vos et al.).

A change from passive enactors to active designers of new teaching material requires professional development (PD). While teachers regularly adapt existing

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teaching materials for their lessons, larger and more systematic curriculum design poses challenges to them (Penuel & Gallagher, 2009). Teachers generally do not feel confident in designing innovative curriculum materials and they find it difficult to think as designers do (Bencze & Hodson, 1999; George & Lubben, 2002). To successfully involve teachers in teaching and designing new context-based materials, PD is needed through which teachers should become motivated for change, understand what the innovation is good for, and gain commitment and ownership with respect to new curriculum and to their new role as designers. In other words, teachers should become empowered for teaching and designing context-based chemistry education (Howe & Stubbs, 1996).

This paper starts with a short introduction to the innovation process for upper secondary Chemistry Education in the Netherlands. This innovation process had large implications for the teachers, so the next section gives a theoretical framework for PD and the empowerment of the teachers. This leads to two research questions: a) *what are the components of a framework for designing and evaluating a programme to empower teachers for context-based chemistry education?* And b) *to what extent does the elaboration of this framework indeed empowers chemistry teachers for context-based education?* Because much is unknown about such a framework, design-based research was used to answer these questions, to design a framework and to evaluate this framework empirically with successive groups of teachers. The findings show that to a large extent the elaboration of the designed framework initiated the intended empowerment. This paper then ends with a discussion on the encountered difficulties and recommendations for researchers and teacher educators.

THEORETICAL FRAMEWORK

This study aims to investigate PD leading to empowerment of chemistry teachers for context-based chemistry education. Many studies have focused on the outcomes and impact of PD (Supovitz & Turner, 2000; Jeanpierre, Oberhauser, & Freeman, 2005). More recently, research into teacher PD has examined the process of PD and not only its outcomes (Hanley, Maringe, & Ratcliffe, 2008; Van der Valk & De Jong, 2009). According to Hewson (2007), insights into the PD during a programme can provide valuable information about the design of the PD programme. By focussing on PD, outcomes can be connected to elements of the programme, and it can be studied which elements contribute to specific outcomes.

The Need for a PD-Framework

To investigate the PD leading to teacher empowerment, a programme needs to be designed with explicitly formulated design principles before it is carried out and evaluated. This requires a framework of coherent design principles that provides guidelines on how to combine the components of such a programme into a coherent design, based on a description of the intended process of PD. Several general frameworks have been published each highlighting different aspects of science teacher PD (Bell & Gilbert, 1996; Loucks-Horsley et al., 2003; Fishman, Marx, Best, & Tal, 2003).The framework of Bell and Gilbert (1996) focuses on teacher development during in-service programmes and describes interrelated strands of their personal, social and professional development. The framework of Loucks-Horsley, Love, Stiles, Mundry and Hewson (2003) highlights the need for developers of such programmes to pay explicit attention to a range of knowledge bases, to the wide variety of PD strategies to the context of their particular programmes, and to critical issues that arise for any program as they design their programs. The framework of Fishman, Marx, Best, and Tal (2003) stresses the importance of being explicit about the connections between programme, teacher practice and student learning. Bell and Gilbert's framework focuses on describing teacher development only, and it does not provide information on how to design PD programmes. The frameworks described by Loucks-Horsley et al. and Fishman et al. focus solely on professional developers and they both lack an adequate description of teacher PD. Although these frameworks provide valuable insights on teacher PD they do not provide guidelines for the design of PD programmes and for the analysis of teacher PD during these programmes. Therefore, a new framework has to be developed which integrates aspects of existing frameworks and teacher PD during context-based curriculum innovations. This framework should consist of a coherent set of design principles for the programme and should provide a description of the PD that is expected to take place.

When a substantial educational change is required, acquiring new knowledge and skills alone is not sufficient. Teachers need to be motivated for change, understand what the innovation is good for, and gain commitment and ownership with respect to educational change. In this study, PD of teachers is conceptualised as teacher empowerment (Howe & Stubbs, 1996). Empowerment is seen as a process by which teachers take charge of their professional and personal growth (Short & Rinehart, 1992). Teacher empowerment consists of several dimensions, like teachers' participation in decision-making that affect their work (involvement), a feeling of control over various aspects of their working life (autonomy), the perception that their daily practice contributes to their professional growth, and the perception that they have the understanding, skills and ability to help students learn (self-efficacy).

Research Question

The aim of this study was an improved understanding of the PD leading to teacher empowerment for context-based chemistry education. This improved understanding will be captured in a PD framework used to design a programme. Therefore the general research question is: To what extent does a PD framework empower chemistry teachers for teaching and designing context-based education?

METHOD

Setting of the Study

In 1999, a group of concerned curriculum experts proposed making Dutch upper secondary chemistry education more meaningful for students by embedding chemistry concepts in context. To involve teachers in the innovation, the expert group advocated establishing networks of teachers working on the design and evaluation of new context-based units (Bulte et al., 2000). Their proposal initiated a nationwide discussion about the chemistry curriculum. A survey of Dutch chemistry teachers showed that a substantial number of these teachers were dissatisfied with the existing curriculum, and they wanted a stronger emphasis on the societal aspects of chemistry (Van Driel, Bulte, & Verloop, 2005).

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

In 2003, these recommendations became the official policy of the Dutch Ministry of Education for a new context-based chemistry curriculum (Driessen & Meinema, 2003). In 2004, eight networks were formed, with teachers from 41 different schools. From 2004 to 2010 these networks designed 45 different context-based units, which were distributed among 170 schools. In the meantime, a new national examination programme was developed, which was implemented in 2013. Currently, the innovation is in a new stage, and new design-networks are being set-up with new teachers and coaches (Apotheker, De Kleijn, Van Koten, Meinema, & Seller, 2010).

This study was mainly carried out in the setting of the early stages of the innovation. In this period the context-based curriculum innovation evolved from a call for discussion by a small group of concerned stakeholders into a nation-wide project on context-based chemistry education supported by the Ministry of Education, involving many teachers and researchers in PD and design.

Research Strategy

This study used design research (Cobb, Confrey, diSessa, Leherer, & Schauble, 2003; Lijnse, 2005) in order to answer the research question and to study teachers' PD in detail. The design research strategy consisted of two research cycles. The first research cycle started with a review of literature on teacher-based and context-based curriculum innovation, strategies for teacher PD and perspectives on learning. From the results of this review, a theoretical framework was synthesised. The first design research cycle started with the design of a theoretical framework for initiating teacher empowerment. The framework is used to describe and evaluate teachers' PD that is expected to take place. Next, this framework was elaborated into a programme, which was carried out with a group of six teachers. Both the programme and the framework were evaluated. The second research cycle started with adjusting and optimising the framework and the programme. Subsequently, the optimised programme was carried out with a new group of seven teachers. Both the programme and the framework were evaluated. Testing the designed empowerment process took place in small-scale case studies, with groups of teachers as the unit of analysis.

Data Collection and Analysis

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

The first and second author independently analysed the empirical data. All fragments (individual teacher statements and group discussions) relevant for teachers' PD and teachers' empowerment were selected from the transcripts of meetings and interviews and compared. If both researchers selected the same fragment, then it was used for further analysis. If not, it was discussed until they reached a consensus about the usefulness of the fragment. To determine teacher empowerment in teaching and designing a context-based unit teacher statements were categorised in terms of their 'involvement in decision-making', 'autonomy' and 'self-efficacy'; these categories were delineated from the concept of empowerment (see the section on the need for a framework for teacher PD). In this study, empowerment of chemistry teachers is operationalized as professional growth (teachers should understand the use of contexts in chemistry education and they are able to teach and design context-based chemistry education) and personal growth (teachers should feel confident about their new roles as teachers and designers of context-based chemistry education). Personal growth is operationalised as: teachers feel involved in decision-making, and experience autonomy and self-efficacy in teaching and designing (Short & Rinehart, 1992). When teachers said that they felt to have an active role in curriculum innovation, this was categorised as perceiving a great deal of involvement in the decision-making. When teachers said that they felt to have a large degree of control over the curriculum innovation this was categorised as showing autonomy. When they indicated that in their perception they could be 'effective in building programmes for students and influence students' learning, this was categorised as self-efficacy. Furthermore, four categories to indicate the number of teachers were used: all (7 teachers), most (4 to 6 teachers), some (1 to 3 teachers) and none (0 teachers). Calculating the percentage of fragments coded equally by both researchers, an inter-coder agreement of 80% was achieved which is regarded as the lower limit for a substantial level of agreement (Miles & Huberman, 1994). The result of the analysis was a description of the PD in terms of group discussions and individual teacher statements. Both the first and second author compared and discussed their descriptions until consensus was reached on the findings. Finally, this description was discussed with the third and fourth author to accomplish final consensus (investigator triangulation: Janesick, 2000).

FINDINGS

The First Research Cycle

Design of the framework. To identify suitable and specific goals for the framework, literature on teacher-based curriculum innovation was analysed (Stolk, Bulte, De Jong, & Pilot, 2009a). Three goals were specified for empowering chemistry teachers for context-based chemistry education:

- Teachers understand the use of contexts in chemistry education,
- Teachers are able to teach and design context-based chemistry education,
- Teachers feel confident about their new roles as teachers and designers of context-based chemistry education.

With these goals in mind, we reviewed literature on PD of (science) teachers and identified four suitable PD strategies (Stolk et al., 2009a):

- Providing access to innovative units and providing opportunities to practise with these units,
- Organising reflection on practical experiences,
- Stimulating collaboration with peers, coaches and supervisors,
- Organising the design of innovative units by teachers.

From a review on perspectives on learning, we considered Galperin's theory of internalisation of actions to provide a useful starting point (Stolk, Bulte, De Jong, & Pilot, 2009b). Galperin's theory consist of a step-by-step strategy to master an action: building up the motivation, orienting on the action, providing the opportunity to carry out the action, and evaluating the PD and results. During the mastery of an action, the orienting basis plays an important role. An orienting basis consists of information by which the learner is guided along in the execution of an action. To prepare for action, learners create a preliminary orienting basis. When carrying out an action, they apply their orienting basis, and during reflection of the execution of an action, learners expand their orientating basis. When, after reflection on the execution of an action, the orienting basis is expanded, this can act as a preliminary orienting basis for a new, more mental, action (Arievitch & Haenen, 2005; Terlouw, 1993, 2001).

The goals, PD strategies, and Galperin's theory were synthesised into the following framework, see Figure 1.

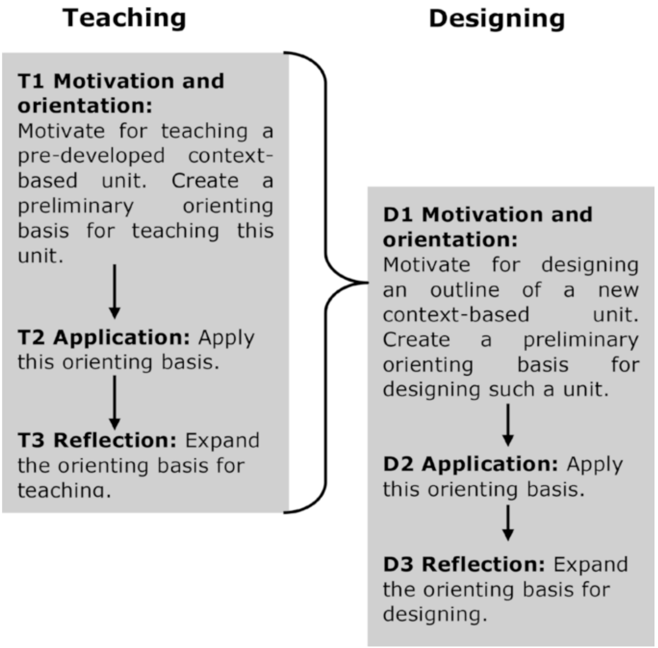


Figure 1. The PD framework used in the first research cycle

The framework contains two strands consisting of three phases each. First, teachers create, apply and expand an orientation basis for teaching a pre-developed context-based unit. At the same time they create a preliminary orienting basis for designing a new context-based unit. Subsequently, teachers apply and expand their preliminary orienting basis for designing a new context-based unit.

Design of the programme. The pre-developed context-based unit used in this research cycle originated from the group of experts as described in the Setting of the study (p. 189). 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 (Jansen & Kerkstra, 2001):

- 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' see p. 9).
- 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. 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.

The framework was elaborated into the following programme (Table 1):

Six experienced chemistry teachers participated in the first research cycle. Four teachers had more than twenty-five years of teaching experience each; two teachers had a range of five to ten years of teaching experience. They were also all from different secondary schools and participated voluntarily in the programme. The programme consisted of a series of five three-hour meetings in a six month period. Between the second and the fourth meeting, all teachers taught the pre-developed context-based unit with their students in Grade 10 (ages 15 and 16) in a pre-university stream. The project staff included the first author and the third author. They designed

Table 1. Overview of the programme during the first research cycle

Phases		*Activities*
D1	T1	A group of teachers, supervised by a coach, carry out the introductory student experiment about the absorbing capacity of a disposable diaper, and they develop research plan for one the inquiry projects. The 'need to know' from the context-based introduction and the application of chemistry concepts during the inquiry projects are discussed.
	T2	The teachers individually teach the context-based unit in their classes.
	T3	The teachers reflect on their experiences with the context-based unit.
D2		First, the teachers design an outline of an introductory experiment which should evoke 'a need to know' for the chemistry concepts in a well-known chemistry textbook chapter and they rearrange the chemistry concepts according to the students' need to know. Second, the teachers design an outline of an inquiry project in which students can apply these chemistry concepts.
D3		The teachers reflect on their experiences with designing an outline of a new context-based unit.

all meetings. The third author, who was the group's coach, led all meetings, with the first author present for observations.

Evaluation of the programme. All teachers reported that the introductory experiment evoked a lot of enthusiasm among their students. However, they all reported to encounter difficulties in motivating students to study the chemistry concepts about the molecular structure of the super absorbent material. 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 connections between the context-based introduction, the chemistry 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 the design activity, all teachers encountered difficulties in designing a context-based introduction. As one of the teachers puts it:

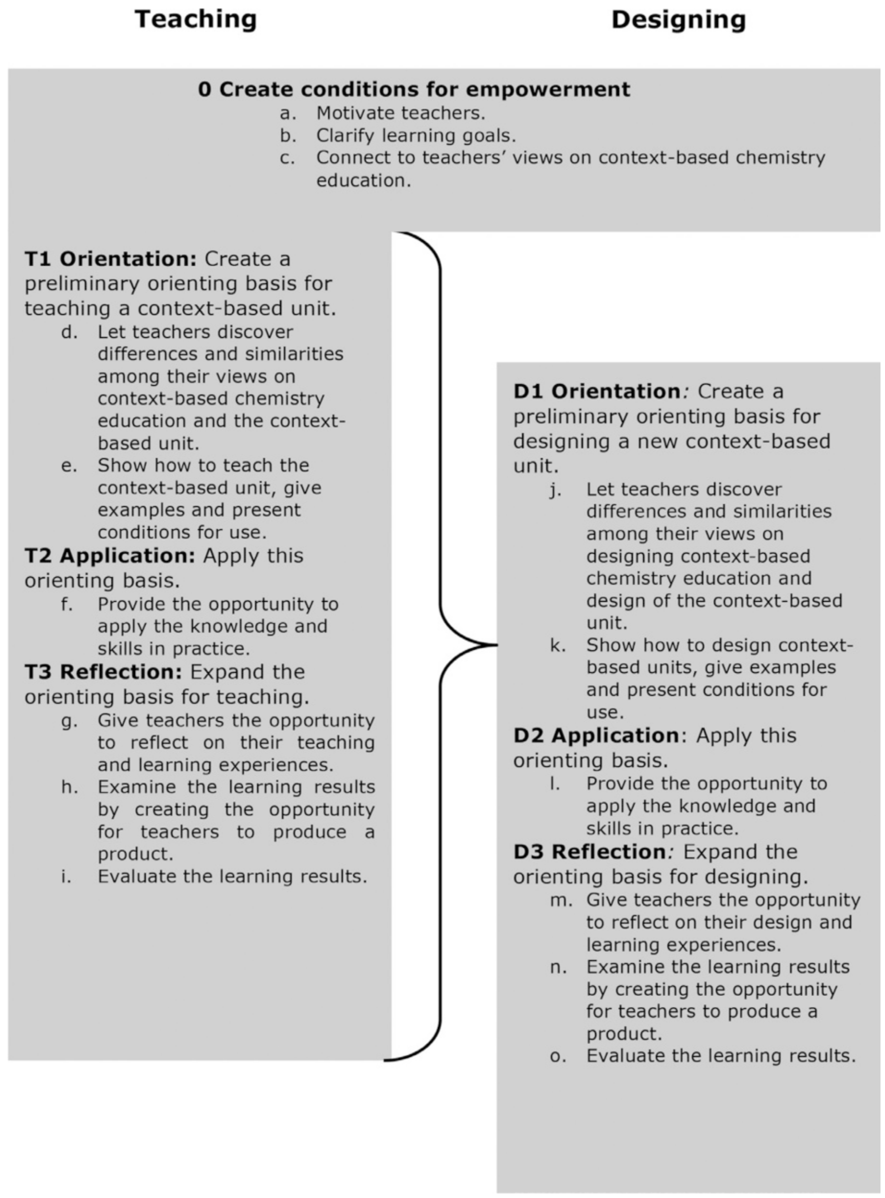
> It is difficult to design a proper introduction (…), it is difficult to assess. Something that students consider as very simple can be offered it in such a way that they start to consider it as interesting. I had never expected that. For instance, regarding that diaper, they were more enthusiastic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

From the evaluation of the programme (Stolk, De Jong, Bulte, & Pilot, 2011) it was concluded that:

- in the context-based unit, students' 'need to know' was not properly satisfied,
- when designing an outline of a context-based unit, teachers had difficulties with designing a suitable context,
- the phases and strategies from the framework did not provide sufficient guidance in designing the programme's activities.

The Second Research Cycle

The refined framework. To improve the guidance of the framework in designing the programme's activities, it was decided that instructional functions could be useful. Instructional functions are general operations or measures that have to be implemented all 15 (see Figure 2) in order to complete the stages of a learning process, and they form a transition between the phases and the activities of the programme (Mettes, Pilot, & Roossink, 1981). Instructional functions provide guidelines to design and plan the programme's activities, and they make these activities more effective and transparent (Terlouw, 2001). The refined framework in Figure 2 reflects the links between the phases including the instructional functions (Stolk, Bulte, De Jong, & Pilot, 2012).



Teaching

Designing

0 Create conditions for empowerment

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

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

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

T2 Application: Apply this orienting basis.

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

T3 Reflection: Expand the orienting basis for teaching.

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

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

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

D2 Application: Apply this orienting basis.

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

D3 Reflection*:* Expand the orienting basis for designing.

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

Figure 2. The refined PD framework used in the second research cycle

Design of the programme. The results from the first research cycle, suggested that the pre-developed context- based unit did not satisfy students' 'need to know'. To improve the link between the context-based introduction and the chemistry concepts, students' questions about super-absorbent materials were elicited during the introduction. In addition, the traditional sequence of chemistry concepts (which started with small simple organic compounds and proceeded via synthesis of polymers towards the structure of super absorbents) was reversed in order to align them with the expected 'need to know' in students' questions. Furthermore, 'concept-related research hypotheses', in which students were asked to use chemistry concepts in their research hypotheses, were included in the context-based inquiry projects to strengthen the link with the chemistry concepts (Bulte & Genseberger, 2003).

The findings from the first research cycle indicated that teachers had difficulties with creatively designing a suitable 'need to know' context with given concepts. Therefore the design activity was adapted in such a way that the teachers had to select a suitable 'need to know' context from a given set and select and structure its accompanying concepts. The optimised framework was elaborated into the following programme (Table 2).

Table 2. Overview of the programme during the second research cycle

Phases		*Activities*
D1	T1	A group of teachers, supervised by a coach, carry out the introductory student experiment about the absorbing capacity of a disposable diaper, and they develop a research plan for one of the inquiry projects. The 'need to know' from the context-based introduction the application of chemistry concepts during the inquiry projects and their views on context-based education are discussed,
	T2	The teachers individually teach the context-based unit in their classes.
	T3	The teachers reflect on their experiences with the context-based unit.
D2		First, the teachers select a suitable context-based introduction from a given set of possible introductions. Second, they select and structure chemistry concepts that students need to study in order to satisfy their 'need to know', and they develop an appropriate context-based inquiry project.
D3		The teachers reflect on their experiences with designing an outline of a new context-based unit.

Seven experienced chemistry teachers participated in the second research cycle. Three teachers had more than twenty years of teaching experience each; the other four teachers had between three and ten years of teaching experience. They were all from different secondary schools and participated voluntarily in the programme. The schools financial compensated the teachers for their participation. The programme consisted of a series of five three-hour meetings in a six month period. Between the second and the fourth meeting, all teachers taught the improved pre-developed context-based unit with their students in Grade 10 (ages 15 and 16) in a pre-university stream. The project staff included the first author, the second author and a coach (an experienced teacher educator). The coach led all meetings, with the first author present for observations.

Evaluation of the program. During the first meeting (T1), teachers carried out the diaper experiment, and they anticipated the types of questions that their students were likely to ask. All teachers recognized that the experiment would generate many questions among students. They also acknowledged that these questions would be geared towards further inquiry of the super absorbents and not towards explaining its properties by its molecular structure. As intended, the teachers concluded that the selection and reformulation of student questions would encourage students to answer their questions using the appropriate chemistry concepts. They reformulated the anticipated student questions and discussed the results. For example, they reformulated 'What happens when you swallow a mouthful of superabsorbent?' into 'What will happen with the super-absorbent molecules if water is being absorbed?'. Finally, all teachers agreed that showing the questions in a central place in the classroom while teaching the chemistry concepts is an effective strategy.

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

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

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

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

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

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

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

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

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

Coach: So you would be looking for a way to reformulate the question, which focuses student thinking towards the molecular structure of super absorbents, without introducing chemistry concepts into the question, in such a way that students would recognize their own question. We have seen several examples of that kind of reformulated questions which give you an opportunity to focus student thinking in the desired direction.

This transcript also demonstrates the different roles of the coach. He focused the discussion (on an important aspect of this reformulated question) without presenting his opinion on the subject, posed clarifying questions, involved other teachers in the discussion by asking their opinion and summarized and generalized the outcomes of the discussion, thereby stimulating the teachers to contribute their own professional expertise (Stolk et al., 2012).

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

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

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

After the teachers had become more acquainted with the context-based unit, the coach encouraged them to discover differences and similarities in their views on context-based chemistry education and the context-based model. First, the coach asked teachers to summarize their views on contexts by using the answers from their pre-programme questionnaire. All teachers had difficulties expressing their views on contexts. Secondly, the coach asked the teachers whether the context-based model met with their expectations. Most teachers indicated that it did, as one teacher stated:

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

During activity T1, the teachers explored, to a large extent, strategies for teaching the context-based unit. They emphasized the importance of student ownership. In the interaction between the program and the teachers, the role of the coach proved important in guiding the teachers' discussion and summarizing their input thus fulfilling function e (Figure 2). Although the context-based model seemed to be connected to teachers' views (function c), they did not become fully aware of the differences and similarities between their own views on contexts and the context-based model (function d). It appeared to be difficult to guide teachers towards making their views explicit. Thus, function d was not properly fulfilled in the implemented program.

After teaching (activity T3, Figure 2), all teachers were satisfied with the quality of the questions their students formulated, and were enthusiastic about teaching the context-based introduction. For example, two teachers reported:

> I really liked the approach, and my students are very enthusiastic about the introduction (self-efficacy).
>
> It is satisfying that I could refer to some relevant student questions when teaching of the chemistry concepts (self-efficacy).

With respect to the concept-based inquiry projects, none of the teachers were satisfied with the concept-related research hypotheses. For example, one teacher stated that:

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

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

In summary, all teachers reflected on their teaching experience, and their remarks indicated self-efficacy, involvement in decision-making and autonomy. The teachers proposed to adapt the strategy of generating concept-related research hypotheses. As a result of the participation in the programme, the teachers felt confident in teaching a context-based unit (Stolk et al., 2012).

During the design activity, all teachers were aware that they did not create a new context-based introduction from scratch, and they acknowledged this as a crucial, yet difficult step in designing a context-based unit. In order to design such a new context-based unit, they suggested working as a group, and requiring appropriate resources, preliminary ideas on a 'need to know' problem and ideas about an inquiry. Teachers' statements below illustrate these views:

> It is impossible to do this myself (…) when I am not provided with time and resources (autonomy).
>
> Different people working together have varying ideas and evoke questions which you would not have thought of on your own (self-efficacy).

All teachers had reservations about designing new context-based units from scratch. However, they intended to implement the students' questions in their teaching practice, as illustrated by the statement below:

> Using student questions was completely new for me; I never did this before. I was pleasantly surprised by the quality of the questions my students wrote down (…) I will use this strategy more often in the future, for example, in the ninth grade when I teach the topic of acids and bases (decision-making).

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

The implemented PD programme functioned well: 13 out of 15 functions were fulfilled. Three factors had a major influence on the fulfilment of the functions. These factors were: The input of teachers' professional knowledge, the programme's designing activities, and the coach. The input of teachers' professional knowledge was apparent in the discussion of the adaptations of the context-based unit (activities T1–T3). The findings showed that teachers suggested the need for careful reformulating students' questions in order to ensure student involvement in the unit, altered the structure and sequence of the chemistry concepts, and proposed adaptations to context-based inquiry projects. The input of teachers' professional knowledge contributed to the fulfilment of function e 'show how to teach the context-based unit' (see Figure 2). In addition, the results also revealed that, teachers had difficulties with explicating their views on context-based education. Although, the tacit and localised nature of teachers' professional knowledge might have hindered fulfilment of function d, the teachers did became aware of their difficulties.

Based on the results of the first research cycle, the design activity (D2) became more structured and closed in the second research cycle. During the orientation on designing context-based units (D1, Figure 2), strategies for designing context-based units were not explicitly described or explored (function j, Figure 2). However, the results showed that teachers were able to design an outline of a new context-based unit. It can be concluded that without an explicit orientation on design strategies (function j), the design activity contributed to the fulfilment of function l. The findings also revealed that the coach had a large influence on the fulfilment of the functions. During activity T1, he encouraged teachers to contribute their own professional expertise (function e). Also during activity T1, the coach ensured that teachers' personal goals were made explicit and acknowledged, so the discrepancies between the goals of the programme and teachers' personal goals had no repercussions for teacher participation (function b). He also acknowledged their input and ensured progress by carefully guiding and focusing activities and group discussions. From the findings, it can be concluded that the input of teachers' professional knowledge and the active role of the coach enriched the implementation of the programme, and contributed to teacher empowerment.

CONCLUSION, DISCUSSION AND RECOMMENDATIONS

Conclusion

The general research question guiding this study was: To what extent does a PD framework empower chemistry teachers for teaching and designing context-based education? From the findings it can be concluded that the main activities of the programme, (teaching a pre-developed innovative unit and (collaboratively) designing a new innovative unit), contributed to the empowerment of teachers for teaching and designing context-based chemistry education. In general, teaching the context-based unit contributed to teachers' motivation for and understanding of context-based chemistry education, but it also made them aware of the difficulties when teaching context-based chemistry. Designing an outline of a context-based unit made teachers aware that they had difficulties with creatively designing a new context.

These findings, however, also showed that the current framework did not sufficiently take the role of the coach and the professional knowledge of teachers into account. The extent of the contribution, however, depends not only on the way these activities were elaborated in the programme, but also on teachers' beliefs, knowledge and attitudes about chemistry education and PD. Little can be said about the extent in which activities have contributed to the PD of individual teachers. Investigating changes in knowledge and beliefs of individual teachers and investigating whether teachers actually participated in design groups (as part of the context-based innovation) was beyond the scope of this study.

Discussion and Recommendations

Both the context-based model and the pre-developed context-based unit play an important role in the PD framework. One of the underlying assumptions of the framework is that the context-based unit would satisfy students' 'need to know' when designed according to the context-based model. Results from both research cycles indicated that the pre-developed context-based unit did not sufficiently satisfy students' 'need to know'. Although the unit was adapted after the first research cycle, the context (disposable diapers) and the model underlying the unit remained the same. A similar result was reported by Bulte, Westbroek, De Jong and Pilot (2006), who implemented and evaluated a module on water quality, developed according to the context-based model. They concluded that: 'the context-based model (…) did not induce in students a "need-to-know" at the moment the students were to extend their knowledge. The concepts (…) only became meaningful afterwards during the application of these concepts, and was not planned on a "need-to-know" basis from the perspective of students' (Bulte et al., 2006, p. 1071). To incorporate a coherent 'need to know' in context-based units, these authors proposed an ‘authentic practice’ as an alternative model for context-based chemistry education. Several case studies have been conducted which use authentic practices to develop context-based units. These studies have shown that the problems with the context-based model can be circumvented (Westbroek, Klaassen, Bulte, & Pilot, 2010; Prins, Bulte, & Pilot, 2011).

An important characteristic of the PD framework is the orientation on designing a new context-based unit. It was assumed that teaching a pre-developed context-based unit would be a suitable orientation on designing an outline of a new context-based unit. The results from both research cycles have shown that teaching a context-based unit does not provide teachers with a preliminary orientation basis for creatively designing a new context-based unit. The orientation on designing used in this study differs from other teacher design groups (Voogt et al., 2011). These groups generally design new curriculum materials, using pre-developed curriculum materials as an example, followed by teaching and evaluation of these newly designed materials. Designing new curriculum materials with the aim of teaching and evaluating them, is likely to provide teachers with a sense of purpose for the design activities. Teachers are more likely to learn when they can apply the results of their learning directly in their teaching practice (Borko, Jacobs, & Koellner, 2010). To accomplish such a sense of purpose and to provide teachers with an appropriate orientation on designing, the following PD strategies could be incorporated in the programme. At the start of the programme, teachers and the coach create a shared vision of designing context-based chemistry education. During the design activity, teachers should be provided with resources from which they can elicit suitable contexts themselves. After designing a new context-based unit, teachers should have an opportunity to teach and collaboratively evaluate their newly designed materials. Whether these strategies would contribute to a sense of purpose among teachers for designing a new context-based unit could be the subject of further study.

The PD framework does not mention the coach. Findings from the second research cycle showed that the coach contributed substantially to the empowerment of the teachers. These results indicated that the coach played different roles during the implementation of the programme. These roles can be described as: (i) ‘seeking common ground’ when the coach makes teachers’ personal goals explicit and acknowledges these goals, (ii) ‘hunting for treasures’ when the coach encourages teachers to contribute their professional expertise to the group, especially during the reflection phases and (iii) ‘catalysing’ when the coach stimulates group discussions by introducing his/her own opinion and when the coach carefully guides and focuses programme activities (Deketelaere & Kelchtermans, 1996). An effective coach should be able to play these different roles, and understand when to play them during the implementation of the programme. Because of the focus of the research on the teachers and the programme, the role of the coach was not investigated thoroughly.

For further understanding of the PD leading to teacher empowerment for context-based chemistry education, the roles and expertise of the coach during the design and implementation of the programme should be the subject of further study (Van Driel et al., 2013). In addition, this kind of research could contribute to the framework, by generating guidelines for coaches on how to interact with experienced teachers during this kind of PD programmes.

The findings are based on two small groups of teachers and two coaches. Therefore, caution is needed in generalising the findings. Because the research was carried out in the initial stage of the curriculum innovation, these teachers may have been 'front-runners' in the innovation process and therefore they probably were not representative of the majority of chemistry teachers in the Netherlands. To improve the feasibility of the framework, it needs to be examined in more case studies, not only with a new group of teachers (e.g. followers in the innovation) or with a different coach but also within a new (context-based) curriculum innovation and with a new team of researchers-developers (Borko et al., 2010).

Context-based education is expected to be an important way to teach chemistry (cf. Smith, 2011). Attempts to empower teachers for context-based chemistry education should not be limited to in-service teachers, but also focus on pre-service teachers. Teacher educators should ensure that these new teachers learn to understand the key aspects of context-based education and should provide them with specific skills required for teaching and designing context-based education. Discussions with student teachers about the meaning and implications of these aspects might help them to understand the differences between the traditional and context-based teaching materials regarding vision and teaching strategy, and to determine which teaching activities best fit the specific demands of classroom reality. Moreover, teacher educators should teach subject matter courses through contexts, and discuss their course design with their students ('teach as you preach'; Swennen, Lunenberg, & Korthagen, 2008).

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

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12. CONTEXT-BASED SCIENCE EDUCATION IN SENIOR SECONDARY SCHOOLS IN THE NETHERLANDS

Teachers' Perceptions and Experiences

INTRODUCTION

Chemistry, physics, and biology curricula for upper secondary education[1] in the Netherlands are characterized, like in many other countries, with poor coherence within and across subjects as well as with a lack of content relevance for a large group of students. Most programs are fragmented and overloaded with content. As a result, most students lack interest in science, and only few students decide to choose science-based subjects as part of their program of study in upper secondary education and to enrol in post-secondary science-based studies (cf. CVS, 2003).

In an attempt to cope with these problems, the Dutch Ministry of Education mandated subject-specific Curriculum Reform Committees to develop new examination programs for senior secondary biology, physics and chemistry education using a context-based approach. In this approach, students master chemical, physical, and biological concepts 'in context' (CVS, 2003; Goedhart, 2004). These pilot programs have been piloted in senior secondary schools in the period 2007–2010.

This chapter looks at the perceptions and experiences of teachers who have been part of the pilot implementation and who were respondents in the evaluation of the context-based program chemistry, physics and biology in the period of 2008–2010. It starts with a short overview of the issues related to context-based science education, and the views of the three reform committees developing the context-based programs. This is followed by the perceptions and experiences of teachers. The results presented are based on a longitudinal evaluation of these pilots (Kuiper et al., 2011a). The chapter closes with a section drawing conclusions.

CONTEXT-BASED SCIENCE EDUCATION

In the late 1990s, Millar and Osborne (1998) analysed the achievements and shortcomings of science education in the UK in their famous publication called 'Beyond 2000'. They listed as major achievements, amongst others, the fact that science was now a universal feature of the school curriculum for pupils aged 5–16 and that '80% of pupils undertake a double science GCSE at age 16 in a programme

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which covers all the major sciences', (p. 2) and that the 'significance of science is reflected in the fact that it now occupies the curriculum high table with literacy and numeracy as the essential core of the primary curriculum' (p. 3).

Identified problems with school science included the fact that it failed to create 'a sense of wonder' in pupils, that it was a list of facts to be learned without much coherence or relevance and coherence, its mid-twenties century focus thus creating a mismatch between science in the media and its dull and uninspiring lessons in the classroom.

Reform initiatives like *Salters' Chemistry* in the UK and *Chemie im Kontext* (see chapter 6) in Germany based their thinking and development activities on 'Beyond 2000'. Similar to these initiatives, a chemistry committee in the Netherlands (CVS, 2003) indicated that the chemistry curriculum up to that time had its primary focus on a sound development of chemical concepts and on scientific and analytical thinking. Applications of concepts and societal issues related to chemistry appeared to only receive attention once the theoretical treatment of concepts had been completed. It concluded that such a focus was not any longer appealing for students in senior secondary education, and that the knowledge society of the 21st century required an innovative approach to teaching and learning. The thinking by the committee was that a context-based approach would be more interesting for a broad group of students. This analysis is largely in line with empirical evidence gathered in the UK (e.g. Bennett, 2005; Bennett, Lubben, & Hogarth, 2007) that context-based science education had indeed an appealing and motivating effect on students, but that student learning did not improve.

In general terms, the renewed context-based science education in the Dutch upper secondary schools was thought to contribute to solving problems such as:

- Lack of relevance of the content of the science syllabi, of societal relevancy and of current scientific developments, resulting in little appeal for students;
- Lack of coherence within science subjects, and across the different science subjects, chemistry, physics and biology. The chemistry program has been described as patchwork as the result of which chemistry at secondary schools can be regarded as a 'sedimentary' program caused by renewal upon renewal;
- Content overload of the programs;
- Lack of applications of concepts and connections to current scientific developments, and
- Low numbers of girls opting for science-based programs (physics mainly).

Innovation started with a context-based approach reform committees for each of the three science subjects. Each of these developed a vision document outlining their views on science education and how the new programs would help to support these views.

Although there are differences between the three subjects, the general starting point of this approach is that knowledge is situated; it is embedded in a context. All three science programs emphasize the importance of re-contextualization. Students should learn to re-contextualise concepts in contexts other than the context in which the concepts were originally taught and learnt. In the chemistry program a context is a 'bridge between reality and concepts' (CVS, 2003). In the biology program a context is seen as a practice in a socio-cultural setting (CVBO, 2007; Boersma et al., 2005, 2007). The physics program defines context as a 'practice, situation or problem statement that has or will get meaning by way of conducting activities' (CVN, 2006, p. 39). The latter two definitions have been formulated close to the preferred models presented by Gilbert (2006): 'Context as provided by personal mental activity' (model 3) and 'Context as the social circumstances' (model 4).

Based on the vision documents, the reform committees for the three science subjects have developed draft *examination programs* which specify the goals/contents (the 'what') to be attained and tested in a high stakes exit examination, consisting of an external exam as well as an internal exam. Based on these subject-specific draft examination programs the National Examinations Board elaborated draft *syllabi* – specifying goals/contents to be tested in the external exit examination. The committees also developed *teaching and learning materials* meant to exemplify the intended curriculum reform at the classroom level (outlining the 'how'). For each subject, the Netherlands institute for curriculum development (SLO) has recently started to develop *guidelines* specifying goals/content to be tested in the internal school examination.

The reforms were organized around subject-specific pilots. The pilots have been conducted from 2005 through 2010, with the involvement of 7 to 14 secondary schools per subject from August 2007 through June 2010 (three consecutive school years). The reform committees have advised the Minister about the feasibility of the nation-wide implementation of their new examination programs after completion of the pilots by the end of 2010.

The try-out of the curriculum proposals by (the selective group of) pilot teachers and their students was accompanied by an independent evaluation. The evaluation aimed at finding out to what extent the intended chemistry, biology, and physics curriculum reforms were viable and feasible for the pilot teachers and their students. It was meant (i) to generate suggestions for improvements of the proposals during the pilots, and (ii) to inform a policy-decision after completion of the pilots, to be taken by the Minister of Education about a country-wide up-scaling of the reforms, with research findings – derived from the pilots – about favouring and impeding factors and conditions.

Data from this evaluation are used for the next section of this chapter, which highlights teachers' perceptions of and experiences with the context-based approach in the new science programs.

TEACHERS PERCEPTIONS AND EXPERIENCES

A longitudinal evaluation accompanied the first cohort of teachers (and students) in the implementation of the pilot context-based science programs. This chapter is largely based on measurements at the end of each year of implementation, in the 2007/08 (4hv), 2008/09 (5hv) and 2009/10 (6v) academic years. In the 2009/10 academic year an additional follow-up measurement was conducted with teachers (and students) in 4havo and 4vwo.[2] Results from this final measurement are only used when relevant. Questionnaires and interviews with teachers (and their students) formed the basis for data collection. One section of the questionnaire and interviews dealt with issues pertaining to context-based science education. The results presented here originate from this section focusing on support for context-based education, use of contexts, and the amount to which the new programs deal with relevance, overload and coherence problems (Bruning et al., 2011; Kuiper et al., 2011b, Ottevanger et al., 2011).

Support for the Context-Based Approach

Teachers generally support the idea of a context-based approach in the new science programs. The approach provides a good way to development goals and content of the programs, although biology teachers were initially rather negative about this, see Table 1. Especially Biology teachers (over 80%) feel that the program is new because of the use of contexts. This percentage is much less for chemistry (about 50%) and physics teachers (about 50% or less). Many teachers indicated in interviews that the use of context is not new to them, that they have used contexts also in earlier program, but more in the sense of outlining the possible applications in the real world once the concepts had been dealt with theoretically. In line with this, teachers (chemistry teachers especially) indicate that the new program makes use of contexts

Table 1. Support for the context-based of the new science programs (numbers refer to percentages of teachers agreeing with the statement)

	Chemistry			*Physics*			*Biology*		
Statement	*4hv*	*5hv*	*6v*	*4hv*	*5hv*	*6v*	*4hv*	*5hv*	*6v*
The context-based approach is a good way to develop goals and content for the… program	78	91	71	63	71	78	27	46	75
The … program is new because of the use of contexts	78	36	50	59	47	22	91	77	88
The … program is new because it uses contexts in a different way than before		82	75		71	44		85	63
The … program is new because of its new content	48	64	38	56	59	89	27	8	13
The … program is especially new because of its new didactical approach	57	18	50	38	24	11	73	77	63

in a different way. Biology teachers experience the new program especially as a new didactical approach, much less as new content. Physics teachers see the new program mainly a new program with new content.

Use of Contexts

Pilot teachers are generally positive about the use of contexts in the pilot science programs. Not all teachers feel there is enough time available to develop concepts in contexts. Roughly half of the chemistry and physics teachers think there is not enough time, but about two thirds of the biology teachers feel that there is, see Table 2. For a large majority of teachers the use of contexts is not an end in itself but rather a means to develop concepts. Very few teachers think that the development of concepts will work better without contexts. Also, a large minority of teachers think that the multitude of contexts may distract students from getting to grips with the concepts. Teachers do not generally feel that the contexts used are artificial, although some do. Biology teachers indicate the repetition of concepts in multiple contexts,

Table 2. Use of contexts: Teacher perceptions (numbers refer to percentages of teachers agreeing with the statement)

	Chemistry			*Physics*			*Biology*		
Statement	*4hv*	*5hv*	*6v*	*4hv*	*5hv*	*6v*	*4hv*	*5hv*	*6v*
The … program provides enough room to work with contexts		36	57		67	44		62	75
The … program is new because of the use of contexts	78	36	50	59	47	22	91	77	88
In the … program context the use of contexts is not an end in itself but rather a means to develop concepts	87	73	88	76	94	100	100	85	75
Mastery of concepts in the … program will be better without the use of contexts	13	18	13	12	6	0	9	0	13
The attention required to master concepts and gain insights in … is distracted by the multitude of often changing contexts	30	45	43	47	35	33	36	46	25
The contexts used in the … modules are artificial	30	45	25	44	29	13	20	38	13

and the possibility to teach modern biology as strong points in the new context-based biology program. However, there are also comments like: '*lack of continuity in focus on current developments*' and '*not enough theory*', as a result of the time-consuming context-based approach.

Most teachers present a context as the starting point for learning about concepts – see Table 3. Biology teachers were initially sceptical about developing concepts in contexts (45%, in 4havo first cohort). This increased to 100% in the subsequent years of the pilot.

An important issue in the context-based approach in the new science programs is that students have the opportunity to address concepts in additional, different contexts, so called re-contextualization. Table 3 provides details on how many teachers stimulate their students to use concepts in contexts other than the original context in which the concepts were developed. Biology teachers appear to adhere more importance, or have more time, for re-contextualization of concepts in other contexts than chemistry and physics teachers. In interviews teachers many times indicated that re-contextualization needs time, which is not available with an already overloaded syllabus.

The context-based programs recommend that a question is formulated which can guide the exploration of the context. Up to a third of the chemistry and physics pilot teachers appear to do this, eventually, in 6vwo, see Table 3. This is less for Biology teachers in the pilot.

Table 3. Contexts in the classroom: Teacher experiences (numbers refer to percentages of teachers agreeing with the statement)

	Chemistry			*Physics*			*Biology*		
Statement	*4hv*	*5hv*	*6v*	*4hv*	*5hv*	*6v*	*4hv*	*5hv*	*6v*
In my … lessons I place concepts in contexts	73	69	75	88	88	89	45	100	100
In my … lessons I stimulate students to use concepts once mastered in different contexts than the original context.	78	85	50	71	63	67	100	85	88
Together with students I formulate in my … lessons a question relevant for a context.	20	8	38	6	18	33	0	23	25

Relevance and Attractiveness

The new context-based programs have been designed to address the lack of relevancy of the previous programs. The designers appear to have succeeded in doing so. A large majority of teachers feel that the new programs are relevant for students, personally, societally and scientifically, see Table 4. They also indicated that the context-based approach makes the programs more attractive for students and makes it possible for teachers to pay attention to societal, professional, and scientific developments. Especially biology teachers think that this is the case. To make contexts attractive, contexts used must be recognizable for students, according to a majority of chemistry teachers. Teachers also think that it is useful to distinguish between daily life, world of work and scientific contexts. '*Challenging topics*', and also '*possibility to use current issues in scientific developments*' are some of the comments made by biology teachers.

Table 4. Relevance: Teacher perceptions (numbers refer to percentages of teachers agreeing with the statement)

	Chemistry			*Physics*			*Biology*		
Statement	*4hv*	*5hv*	*6v*	*4hv*	*5hv*	*6v*	*4hv*	*5hv*	*6v*
Dealing with concepts in contexts increases the attractiveness of … for students.	74	55	63	56	71	100	91	77	75
The use of contexts in … makes it possible to pay attention to societal, professional, and scientific developments.	91	73	100	65	88	89	91	100	100
The … program is personally relevant for my students	39	64	50	25	63	89	82	77	88
The … program is societally relevant for my students	83	100	63	44	63	67	91	92	100
The … program is scientifically relevant for my students	57	82	63	31	56	78	73	77	88
Contexts in … need to be recognizable for students	100	64	50	6	18	33	73	23	25
In … it is useful to distinguish between daily life, world of work and scientific contexts	64	45	71	59	59	89	73	54	88

Content Overload

The new programs also aimed to reduce the overload of the existing programs. The relative low scores in Table 5 relate to the issue of content overload. Many teachers, of all subjects, indicate that the syllabus is overloaded. In interviews teachers indicated that this is partly caused by the time needed to develop concepts in contexts. During the pilot especially the reform committee for physics have tried to deal with this problem, with some success, see Table 5.

A second measurement in 4havo and 4vwo in the third cohort reconfirms the overload, despite attempts of the reform committees to deal with it. Only 17% of the chemistry teachers, 33% of the physics teachers and 33% of the biology teachers indicated that the syllabus can be covered in the time available. Teachers adjust the content of the syllabus to deal with this overload. In the words of a chemistry teacher: '*one adjusts. I have scrapped the discussion on climate change*'. The premise of the reform committees was to limit the number of concepts so that there would be enough time to address concepts in a context. '*Good idea*', says another chemistry teacher, '*except that this hasn't happened*'.

Table 5. Content overload: Teacher experiences (numbers refer to percentages of teachers agreeing with the statement)

	Chemistry			*Physics*			*Biology*		
Statement	*4hv*	*5hv*	*6v*	*4hv*	*5hv*	*6v*	*4hv*	*5hv*	*6v*
The **…** syllabus is achievable in the available time		25	25		24	50		23	38

Coherence

A third problem with the existing programs referred to poor coherence. Especially biology teachers indicated that the context-based approach promotes the coherence within a subject (internal coherence), see Table 6. About half or less of the chemistry and physics teachers think that this is the case in their subjects.

Table 6. Contexts in the classroom: Teacher perceptions (numbers refer to percentages of teachers agreeing with the statement)

	Chemistry			*Physics*			*Biology*		
Statement	*4hv*	*5hv*	*6v*	*4hv*	*5hv*	*6v*	*4hv*	*5hv*	*6v*
The context-based approach promotes the coherence within the … syllabus.	57	64	38	31	38	56	82	92	88

The measurement in 4havo and 4vwo in the third cohort on the topic of internal coherence showed that 58% of the chemistry teachers, 44% of physics teachers, and all biology teachers (100%), think that internal coherence is promoted by the context-based approach of the program.

In addition, a majority of pilot teachers (in the third cohort measurement) think that there are enough opportunities in each of the separate syllabi to come to coherence across the science subjects: 92% (Chemistry), 44% (Physics), 67% (Biology).

SUMMARY AND CONCLUSIONS

By and large, teachers of the three science subjects with a context-based approach perceive the programs as new because of the use of contexts, or the use of contexts in a different way than in earlier programs. In the remainder of this paragraph we formulate some conclusions thematically.

Context: Support by Teachers and its use

- Pilot teachers support the idea of context-based science education. This is helpful, for a successful implementation of the pilot programs such support is necessary. However, it will still be a challenge to receive support for the approach from teachers who were not involved in the pilot.
- Pilot biology teachers experience the new program as a new didactical approach, unlike pilot physics teachers who feel the focus of the renewal is mainly content-related.
- Pilot teachers are positive about the use of contexts, but pilot chemistry and physics teachers feel that there isn't always enough time to use these contexts in the preferred way.
- Pilot teachers place concepts in contexts and stimulate students to also use such concepts in different contexts, so called re-contextualization. This is especially the case for pilot biology teachers.

The reform committees for the sciences had set out to address the observed problems with the previous programs: content overload, lack of relevance, and lack of coherence within and across different subjects. For each of these problems, we describe our main conclusions.

Overload. Teaching and learning about concepts in context requires additional time. As a result it is necessary to reduce the number of concepts in the syllabi. Pilot teachers agree with this, but this hasn't happened (sufficiently, yet) in the new syllabi, leading to overload. Further data from the studies suggest that overload is multi-dimensional and relates to the syllabus, teaching and learning materials with more activities than possible in the available time, as well as overload caused by teachers who may still teach components of the old program or have difficulties making a selection from the many suggested activities in the materials.

Relevance. The main success of the new context-based science programs is its increased relevance and attractiveness for students. This is in line with earlier evidence from similar context-based science programs which indicated that attractiveness for students was the main result of a context-based approach (Bennett et al., 2005).

Coherence

- The problem of poor coherence within subjects seems partly solved. Pilot biology teachers think that the context-based approach of the new science programs promote the internal coherence, pilot chemistry and physics teachers much less so.
- The problem of poor coherence between subjects has not received much attention yet, but a large majority of the pilot teachers see opportunities in the syllabi of the separate subjects for coherence across the subjects. Boersma et al. (2010) provided a first step in the direction of coherent examination program starting with a number of common core concepts and contexts organized in themes.

NOTES

[1] Senior secondary education in the Netherlands pertains to grades Secondary 4 and 5 of the senior general education track (HAVO) and grades Secondary 4, 5 and 6 of the pre-university education track (VWO).

[2] Dutch senior secondary education consists of a pre-academic stream, called vwo (3 years: 4vwo – 6vwo) and a pre-professional stream, called havo (2 years: 4havo and 5havo).

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13. CONCLUDING REFLECTIONS ON CONTEXT-BASED LEARNING ENVIRONMENTS IN SCIENCE

In this final chapter we reflect on the papers presented in this book. As such, the different contributions provide a range and variety in Context-Based Learning Environments in Science (CBLES) and associated teaching strategies, as well as an outlook on how to assist and stimulate teachers to develop themselves for creating such environments. How to value and understand these different types of CBLES?

The use of contexts in learning environments in science education has increased in many countries in the last ten years, and now the question arises what the key issues are in this approach, what the outcomes are and what this involves for the competencies of the teachers in such science education. What can understanding of learning environments (LE) contribute to gain more insight in CBLES and to the further development of CBLES. It also leads to the question: What can the research on CBLES contribute to the domain of learning environments?

To answer these questions, we think it may help to construct an overarching framework to typify the different CBLES. To construct this overarching framework, we think that the work by Gilbert (2006) and by Roberts (2007) in the domain of science education on the one hand, and the classification by De Kock, Sleegers and Voeten (2004) in the domain of learning environments research on the other, are good starting points.

AN OVERARCHING FRAMEWORK FOR ANALYSING CBLES

Ten years ago Gilbert (2006) based his description of context-based education on the description of ‘context’ and ‘focal event’ by Duranti and Goodwin (1992). This led to four attributes and to four criteria for the attainment of context-based science learning and to a normative prescription of these in four models (also based on the theories of situated learning, constructivism and activity learning). Roberts (2007) rephrased the differences in the emphases he described earlier into two visions on scientific literacy in school science. These are prototypical extreme positions. Vision I looks inwards to science itself – its products of concepts, laws and theories and its process of investigation. Vision II looks outward at societal situations in which science has a role. The major trend in science education in many countries has been to transform science education in the direction of Vision II. Following this trend, the goals for national science exams in The Netherlands (in 2013) or the

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state science exams in Germany were revised and now involve students' use of real world contexts. So we accept Visions I and II as the extremes in the classification of CBLES. Of course, in between the two extremes there are nuances, but using extremes makes the differences between different LE clearer and gives a better understanding of the developments in CBLES. It also gives a perspective on the wide range of different solutions that are described in the chapters in this book. CBLES is still very dynamic and should reflect the local and cultural differences in which designers and teachers try to innovate science education (including adaptations to national cultures, and developments to national standards).

A review by De Kock, Sleegers and Voeten (2004) suggests that learning environments can be classified into different types, based on a number of underlying principles and assumptions, which in turn define a series of aspects that can be found in any learning environment. They structure their classification along three main aspects of learning environments that influence learning: (1) *learning goals*, (2) the *division of teacher and learner roles*, and (3) the *roles of the learners in relation to each other*. In their work, assessment and examination does not play an explicit role. For the classification of learning environments in context-based science education this is an essential aspect, but because this revision of the exams has been formalised so recently, it is not possible to see the effects in the results of evaluation and research. The educational situation is still very dynamic, and this also influences the need and effects of professional development of teachers, and the redesign by publishers of study materials and school books. The effects of the new goals and exams on the learning environment and the learning and teaching of students and teachers, as is known from the literature on learning environments, will be substantial (Simons, van der Linden, & Duffy, 2000).

In the line of reasoning towards the classification of learning environments as proposed by De Kock, Sleegers and Voeten (2004) three critical principles or assumptions with regard to learning are important, and they determine the goals, divisions of roles between teacher and students and the roles of students in relation to each other: (a) learning is a *constructive* activity; (b) learning is a *situated* activity; and, (c) learning is a *social* activity.

Learning as a Constructive Activity

Constructivism considers learning as more than the reception or transmission of knowledge, which is central to traditional school learning; constructivism is more focused on active and personal construction of knowledge and skills and the development of competencies. As De Kock et al. (2004, p. 146) describe "Most constructivists therefore argue that the most important goals of learning in the school context are problem-solving, reasoning and critical-thinking skills – the active and reflective use of knowledge, and self-regulation skills." From such a perspective, the learning process itself is the most important learning goal and educational objective" (Land & Hannafin, 2000; Simons et al., 2000).

Learning as a Situated Activity

The second principle for the classification of learning environments stresses that knowing cannot be separated from doing, because otherwise knowledge would become decontextualized (Driscoll, 2000). So, this principle is very important for context-based science education. Gilbert (2006, p. 970) refers in this perspective to the theory of situated learning and activity theory (considering "context as a social activity", Van Oers, 1998, p. 480). Situated learning is strongly related to the concept of 'practice fields' (see also the chapter by King in this book). Domain-related practices are also central to the situated learning theory of Lave and Wenger (1991), who assume that "the mastery of knowledge and skills requires newcomers to move forward full participation in the sociocultural practices of a community" (p. 29). The principle that learning is a situated activity implies a different division of roles between teachers and learners than in the traditional school science learning environment. In the traditional learning environment there is no realistic practice field and no realistic context (it is decontextualized); the teacher regulates the process while the learner is dependent on the instructions of the teacher, only carries out the instructions and has little control over his or her activities. When the learning process is highly situated the learners will have to regulate their domain- and practice related use of concepts and skills more themselves. The role of the learner is one of self-regulation (also see the chapter by de Putter-Smits et al., this book): the external control of the learning process by the teacher in the traditional learning environment is replaced by internal control by the learner. "The role of the teacher is to model processes and skills; to monitor learning, thinking and regulation of activities; to provide metacognitive guidance; and to stimulate learners to reflect on their own learning" (De Kock et al., 2004, p. 148; Simons et al., 2000).

Learning as a Social Activity

This third principle in the arguments of De Kock et al. implies that knowledge is a social construct created by a group of learners or a community. This principle combines with the previous principle on 'learning as a situated activity'. Together these have an important place in the arguments for and the design of context-based science education (Gilbert, Bulte, & Pilot, 2011; Bulte, Westbroek, de Jong, & Pilot, 2006). This principle of learning as a social activity has consequences for the division of teacher and learner roles, and the roles of learners in relation to each other (see next sections).

LEARNING GOALS

Regarding the conditions of learning based on the assumptions of constructivism the most important implication involves the goals of learning: the process of learning is considered as a goal in itself ('learning to learn'). In this connection, Simons (2000) argues that the learning process revolves around the execution of three general learning functions: *cognitive, affective and metacognitive*. Within each of the general functions, a distinction can be made between goals and products on one hand, and teaching and learning on the other.

These learning functions concern the integrated use of a specific set of knowledge and learning skills, thus referring to the execution of the various learning functions, as learning to learn is the central goal in such learning environments (De Kock et al., 2004). Therefore these goals should be included in the classification system of the learning goals. However, to focus on the main differences in learning environments we focus in Table 1 on the main goals for traditional and context-based science education (Vision I and Vision II; Roberts 2007).

These reflections lead to the first two aspects under the learning goals in the classification of De Kock et al. (2004): *learning products* and *learning process*. Table 1 gives a summary of these categories for traditional and context-based science education (Vision I and II).

Table 1. Classification of learning goals in learning environments for context-based science education

	Vision I *Traditional science education with context as illustrations*	*Vision II* *Context-based science education, with authentic practices as context*
Learning goals/ products		
Rationale	Emphasis on Fundamental (academic) Science	Emphasis on Science, Technology and Decisions (STD)
Cognitive	Decontextualized concepts, rules, theories and processes	Contextualized concepts, rules, theories, processes and transfer skills
Affective	Preparing for the next course / examination Become better in the subject	Appreciating the relevance (and problems) of science and technology and valuating its collaborative nature
Metacognitive (e.g. learning)	Learn to remember Learn to reproduce and vary on standard procedures	Learning to develop knowledge (need-to-know principle) as coherent and useful patterns of understanding
Teaching/learning process		
Rationale	Behavioural learning	Developmental learning, Apprenticeship model
Situation	The abstract structure of school science and the *textbook* are central	The learners are introduced to and immerged into a *realistic science challenge*
Social setting	Mostly *individual* learning in the implicit role resembling that of a 'copy monk'	*Participating* in learning/creating teams, taking up roles that are typical for science and technology

Table 1. (Continued)

Control	*Teacher control* The learner should follow the instructions of the teacher	*Learner/shared-control*. The doing/learning is largely structured by the intrinsic structure of the challenge
Cognitive	*Ideas* can be *mistakes* and may be pointed out as wrong	*Ideas* are shared and *welcomed* by the students and the teacher in the role of senior-team member
	Creating and exercising abstract concepts on examples largely *simplified* to fit the theory	Continuously testing and improving concepts on *life/realistic* contexts and tasks
	Leading to *(alien) abstractions claiming universal potency*	Leading to *knowledge with proven value* in various contexts
	No specific attention to transfer skills	Learning to de-contextualize and re-contextualize knowledge and skills
Affective	Valuing the *correct reproduction and use in standard situations*	Valuing *relevance for reality* and joint effort to both understand and improve understanding and products
Metacognitive (e.g. learning)	*Little room* for student to practice/learn reflecting, planning, steering their learning behaviour	Continuous *challenge to improve* on reflecting, defining (sub) problems, steps, planning, steering the individual learning behaviour as well as collaboration
Closing	Incentives to *checking for lacks* in learning and knowing	*Challenge* to reflect on outcomes, relevance and opportunities for transfer

THE DIVISION OF TEACHER AND LEARNER ROLES

De Kock et al. (2004) distinguish three instructional paradigms of teacher and learner roles: (1) the behavioural model; (2) the developmental model; and, (3) the apprenticeship model.

> The first paradigm reflects a behavioural model. The teacher instructs the learner to become better in a specific subject. This means that the teacher instructs the learner regarding what should be learned and how, and the learner applies the instructions with the aim of acquiring more of the teacher's expertise. In this model of role division, reinforcement of student activities plays an important role. The reinforcement component is typical for performance-oriented learning environments in which a behavioural model of role division is reflected. However, […] in present-day education, there is a shift from a performance orientation toward a learning orientation.

> Learning environments in which a learning orientation is central tend to reflect the second division of roles, which is in line with a developmental model. In that model the learner learns from the teacher who is questioning, contradicting, or even challenging the learner's personal theories. The learner regulates his or her own learning with the teacher or expert, serving as a coach.
>
> The third division of roles reflects an apprenticeship model of learning. The learner and teacher participate in a shared world with respect to a particular subject. The teacher has considerable expertise in that world and tries to model his or her expertise. The learner in turn, masters a number of domain-related practices by participating in that world and imitating the activities of the teacher. (De Kock et al., 2004, p. 161)

Next to this division in three models or paradigms of learning (behavioural, developmental and apprenticeship) De Kock et al. (2004) place learning environments along a continuum of *control*,

> … ranging from a centralized role for the teacher with an emphasis on control of the learner's responses to a decentralized role for the teacher with an emphasis on facilitation of the learner's learning. […] At one end of the continuum, learners are guided to understand the information that the teacher provides and are construed as knowledge consumers; at the other end, they are regarded as self-directed learners who evaluate their own knowledge, skills, and learning and are thus construed as knowledge producers. (De Kock et al., p. 157)

This range has strong implications for the teacher when they change their learning environments from one end of the continuum to the other.

THE ROLES OF THE LEARNERS IN RELATION TO EACH OTHER

Learning as a social activity stresses the interaction between learners through their participation as members in a community of practice. It is assumed that helping other learners or negotiating, and giving reasons and asking for reasons are needed to construct knowledge.

The implications of the principle that learning is a social process in the first place concern the role of the learners in relation to each other. Three kinds of learning settings are distinguished: *competitive*, *individual* and *cooperative*. "In traditional learning environments, the learners have mostly individual and sometimes competitive roles. "In modern learning environments, cooperative roles for the learners are emphasized […] but learners may also have individual roles" (De Kock et al., 2004, p. 149).

This leads to the classification of learning environments for these two aspects that is summarized and elaborated for the two types of science education in Table 2.

Table 2. Classification of teacher roles and roles of learners for Vision I and II learning environments

	Vision I: Traditional science education with context as illustrations	*Vision II: Context-based science education, with authentic practices as context*
Division of teacher roles	Behavioural model	Developmental model, Apprenticeship model
Roles of learners in relation to each other	Competitive, Individual	Individual, Cooperative

AN EXAMPLE OF APPLYING THE CLASSIFICATION OF LEARNING ENVIRONMENTS

Which learning environments from this classification of types are relevant here for context-based science education? Starting from the origin and ideals of CBLES it is clear from Tables 1 and 2 that for the aspect of the goals of the categories learning products and learning process are relevant, but for the aspect of division of teacher and learner roles, only the developmental and apprenticeship model are relevant, and for the aspect of roles of learners in relation to each other the individual role is relevant but the cooperative role is even more relevant.

We can illustrate this with the study presented in the chapter by King in this book. Two cases of learning environments are described by King in her chapter "*Teaching and learning in context-based science classes*". In summary: In Case Study 1 the chemistry unit involved 19 lessons where the students were required to conduct water quality investigations in groups on water samples collected from the local creek. The teacher provided a map of the locations from which they had been collected. In the first phase the chemistry content was taught primarily in response to student questions when the need arose. In the second phase the teacher taught three teacher-led lessons on chemical theory e.g. intermolecular forces of attraction unrelated to the context of the creek.

Case Study 2 required the students to make weekly visits to the creek where they recorded data on water quality of the creek and the nature of the surrounding flora and fauna. All learning was centralised around the context where the teacher implemented structures that afforded students the agency to connect science concepts with the data collected at the creek. The teacher did not revert to teacher-led transmission of content unrelated to the context.

The two different cases provide much information about the circumstances the learners and teachers were involved in. We describe the classification, using the main aspects and categories as proposed above, adding some issues that are specific for science education.

Learning Goals

Learning products. The overall goal of the courses, as described by King can be interpreted as 'Vision II'. The learning goals are not explicitly described. In case 1 the focus is on the context in the first lessons (environment and health), while in the second part the focus shifts towards concepts (canonical science, emphasis on fundamental science) without relating these concepts to the context. In case 2 the focus is on the context and the need to know concepts in a real world (out of class) learning environment (visits to the local creek). Knowledge of the learning process is not explicitly described as a learning product. The attitude toward the learning content is focused on the context of the environment and health in both cases (but not in the second part of case 1, where the emphasis seems to be 'fundamental science' (Vision I).

The attitude toward the learning process, the cognitive learning process and the cognitive skills nor the affective learning skills are explicitly described as learning products. The social learning skills are important in both cases, because a lot of teamwork is involved as well as whole group discussions. Transfer skills seem to be important through the concept of 'fluid transitions' between contexts and concepts; these skills are described in the discussion in the chapter about the results of observations and experimental measurements of water quality.

Learning process. In the preparatory learning functions the affective and metacognitive categories can be recognized in the challenge of real world problems in the local community: the environment with fishes and swimming, health problems in the local creek, and the planning of activities like measurements and experiments (in case 2), and the need to know principle for understanding concepts. No details are given on the cognitive learning functions.

The executive learning functions involve practicing and applying knowledge in experiments and interpretations of the data or results of experiments (cognitive). The affective learning functions involve the discussions on the results and conclusions about the real world problems, also involving metacognitive learning functions (especially in case 2 during the weekly visits to the local creek, out of school learning environment. The closing learning functions are not described in detail.

Division of teacher and learner roles. In case 1 (first part) and case 2 a developmental model was used with a decentralized role of the teacher and a clear agency of the students in their learning processes. In the second part of case 1 an interesting example of change from Vision I to II in the learning environment took place: the teacher focused on "three teacher-led lessons, featuring intermolecular forces of attraction and the structure of the water molecule, unrelated to the context of the creek"(King, Chapter 5). "[…] the students did not integrate this theory into the main body of their final report […] but rather tacked it on in an appendix, indicating that they perceived it as separate to the context". This suggests a strong change in effect between the two learning environments.

The roles of learners in relation to each other. The main impression of the reported activities is that the learning process is very much cooperative, although some parts may have been individual, so the classification is that both cases are mainly in the category 'cooperative'.

Assessment of learning products. No details are provided in this chapter on the learning results on tests, or products like reports or portfolios.

Physical learning environment. In case 1 the learning environment is inside the school; in case 2 the learning environment is out of the school, in the creek, which is described as an important characteristic in the activities of the learners and the teachers roles.

CONCLUSION

The first conclusion is that a classification of learning environments in CBLES in Vision I and II gives a clear insight in the differences between CBLES cases, in the goals and roles of teachers and learners. The shift in paradigm between these two extremes has important implications for the competencies of teachers and the learning activities of the learners (see last section of this chapter).

The second conclusion is that the information on the learning environments in the context-based science courses, provided in the chapters in this book, is often not sufficient for a unambiguous classification of the designed or realized learning environments. The goals and assessment of the learning environment are not always described. In future papers, researchers are advised to use the aspects and categories of the classification as a checklist for providing the information, in order to relate its outcomes to the features of the learning environments.

However, we can also conclude that some aspects need further elaboration to support designers and teachers in their work on CBLES. We will discuss these in the next section.

ELABORATION OF THE FRAMEWORK

We used the extremes of Vision I and II by Roberts (2007) for the classification of CBLES, but a more nuanced analysis (Aikenhead, 2007; Gilbert et al., 2011) and the chapters in this book suggest an intermediate Vision of the use of 'Context as a Reciprocity between Concepts and Applications', where a situation is "selected as a vehicle through which concepts can be taught. The assumption in the intermediate approach is that there is a cyclical relation between concepts and context throughout the teaching, that is, *after* the concepts are taught, their application in the context is presented, and then a new aspect of the context is focused upon as a prelude to the teaching of new concepts" (Gilbert et al., 2011, p. 823).

Gilbert, Bulte and Pilot see two problems with this approach in the reality of the science classrooms: the focus on the situation (the context) may be easily forgotten during the teaching sequence, and the focus on the science concepts may become the sole focus of attention, so resulting in the Vision I emphasis. And, as Layton (1993) pointed out, the meaning of concepts change as they are used in their applications to specific contexts; so the context should precede the learning of concepts, not concepts first and then applications. For some of the chapters in this book it is not quite clear whether they refer to this intermediate Vision or to Vision II.

Activity Theory

The principle of 'learning as a situated activity' provides some guidelines for domain-related practices but these guidelines that are not specific enough for the designer and the teacher regarding the activities, roles and interactions in learning environments for context-based science education. When we turn to activity theory, the elaboration of this theory for context-based education may provide more insight in the transformation of authentic practices into classroom activities, the succession of activities, motives and tools that are essential for learning environments with an authentic community of practice.

The ideas of using authentic practices in science education is based on the work on activity theory by Engeström (1987), Leontev (1978) and Van Aalsvoort (2004). Activity theory aims to understand the whole of human praxis that is the collective activity systems in a context. This implies firstly analysis of the kind of activities people engage in, but also who is engaged in that activity, their goals and motives, the objects and products in that activity, the rules and norms and the larger community in which the activity occurs. Activity theory differs from other sociocultural theories of learning in some respects: the focus is on shared collective activity as the primary unit of knowledge; activity theory considers conscious learning as emerging from activity, not as a precursor to it (Jonassen & Rohrer-Murphy, 1999) and it emphasizes the relation between activity and society. That makes activity theory an interesting basis for the development of an instructional framework for the transformation of authentic scientific practices into classroom activity systems, such that coherence between activities, content and tools is preserved. The components of an activity are organized into activity systems (Engeström, 1987; Vygotsky, 1978) that are goal-oriented, involve an object of activity (a mental or physical product), and a subject engaged in the activity (an individual or a group of actors). The activity is mediated by tools (physical or mental, such as concepts or heuristics), by rules and division of labour in a community. Jonassen and Rohrer-Murphy (1999) proposed five aspects to analyse the activity system of an authentic practice:

1. Clarifying the purpose of the activity system
2. Analyse the activity system
3. Analyse the activity structure
4. Analyse the mediators
5. Analyse the contextual bounds
6. Analyse the activity system dynamics.

These components can be used for the design of an activity-based instructional framework for transforming authentic modelling practices into contexts for learning (Prins, Bulte, & Pilot, 2016).

It should be mentioned that the classification of CBLES Vision II in Tables 1 and 2 is to a great extent the same as Gilbert's original fourth model 'context as a social activity' that was based on activity theory (Gilbert, 2006, p. 970). The third model by Gilbert refers to 'context as provided by personal mental activity' and as Gilbert describes students 'do not become actively involved. The social dimension of engagement through interaction within a community of practice is missing'. That does imply that model 3 is quite different from the learning environments for CBLES that were described in Tables 1 and 2.

The analysis of the aspects of activity systems provides the designer and teacher with more detailed information for the role of the teacher and the roles of the learners in their interactions in the specific community of practice, and for the sequence of motives and learning activities. This is also the focus of the problem-posing approach for context-based science education that was proposed by Klaassen (1995).

> The problem-posing approach is based on two essential ingredients: The first is that pupils' process of science learning is, at any stage, provided with a local point, in the sense that their reasons for being involved in a particular activity are induced by preceding activities, while that particular activity in turn, together with its preceding activities, induces pupils' reasons for being involved in subsequent activities. The second ingredient is that their process of science learning is, at appropriate stages, provided with a global point, which is to induce a (more or less precise) outlook on the direction that the further process will take. Accordingly it is an essential ingredient of […] devising a didactical structure of the topic […], that one will have to think of appropriate local and global points, and of appropriate ways to induce those. (Klaassen, 1995, p. 111)

An analysis of the activity system in an authentic practice can provide indications for the local and global points, and the succession of those.

These arguments suggest that another aspect should be added to the classification on CBLES learning environments, the aspect of the 'didactical structure of the learning activities' in CBLES. Categories in this aspect might be authentic practices and principles like problem-posing approach and 'need-to-know'. The aspects in the classification system of De Kock et al. (2004) do not provide information to classify the learning environment in enough detail for insight in the relation between learning environments and effects of these.

Inferentialism

The interaction between learners also needs a more detailed theory to provide guidelines for designers and teachers of CBLES. This is supported by the recent discussion on the "semantic theory termed inferentialism, a significant development in contemporary philosophy, which places inference in the heart of knowing" (Bakker & Derry, 2011, p. 5). These authors focus on three challenges in Statistics Education, that are more or less the same as we previously described for science education: (a) inert knowledge; (b) atomic approaches in textbooks and lack of coherence from a student perspective; (c) the challenge of sequencing topics for coherence from the students' perspective" (p. 5).

Inferentialism (Brandom, 1994, 2000) provides an account of concept use that starts with reasoning rather than with representing. This theory has an explicit focus on reasoning (i.e. inference) underpinning concept use. Inferentialism helps to explore the relationships between domain-based inference, concepts and contexts (Bakker & Derry, 2011). Inference is here intended as referring to an implicit and partly unconscious process of reasoning from a sample to a wider universe (not as it is used in statistical inference). With their focus on the three challenges Bakker and Derry argue that they draw three lessons from inferentialism.

The first lesson is "that concepts should be primarily understood in terms of their role in reasoning and inferences within a social practice of giving and asking for reasons, and not primarily in representational terms" (Bakker & Derry, 2011, p. 9), because learning scientific representation certainly does not guarantee the learning of science. The learner of a concept is capable of making a judgement, because human responsiveness involves reasons, not merely causes. In order to do this, the learner needs experience in the 'space of reasons' or 'the web of reasons' in which the concept is used, including the relevance and function of the concept. "It is in the context of reasoning […] that representations (words, graphs, inscriptions, etc.) gain and have meaning. […] We recommend introducing […] concepts and graphical representations in the context of making inferences about what students take to be realistic problem situations" (Bakker & Derry, 2011, p. 11).

The second lesson, referring to the challenge of atomism vs. holism, is "that one cannot inferentially reason with any concept without drawing on its inferential relations to other concepts, because […] one cannot have any concepts unless one has many concepts. For the content of each concept is articulated by its inferential relations to other concepts" (p. 11). Bakker & Derry recommend privileging holism over atomism.

Based on these philosophical lessons, they summarize the third lesson as privileging an inferentialist approach to education over a representational one. They argue that "[…] the development of concepts proceeds through activities in which the concepts function meaningfully. Hence a concept is not first learned formally and then applied, but develops according to the domain of activity (including reasoning) in which it functions" (Bakker & Derry, 2011, p. 12). The inferential relations that form the content of the concept are related to the norms governing the application of concepts, so correct application of concepts, and hence meaning, is learned by activities with others within a normative practice, involving a system of judgements (Vygotsky, 1998). "The inferentialist view alerts us to the normative character of concept use. What counts as valid reasoning, adequate judgment, or correct application of concepts depends on the norms being used in a particular practice" (Bakker & Derry, 2011, p. 12).

Using Statistics as an example, Bakker and Derry describe the implications for the relations between concepts and contexts: "from an inferentialist perspective, a dichotomous distinction between statistics and context is problematic. The distinction suggests that there is 'text', in his case the statistical representations, and 'con-text' – what surrounds this text (cf. Roth, 1996). But as Brandom (1994) and Vygotsky (1998) make clear, a concept cannot be understood merely in its representational form; its meaning is disclosed in a rich system of judgments about a situation. […] Judgments are constituted in and connected by inferential relations within a web of reasons. It is for these reasons that Bakker and Derry suggested the notion of a web of reasons as a more precise and non-dichotomous alternative to that of context." (Bakker & Derry, 2011, p. 23).

This description of the interaction also has implications for the roles of teachers and learners and for the learning goal of social and communicative skills, for example listening and explaining things to others. This listening and explaining should be considered in the perspective of 'giving and asking for reasons', as mentioned in the theory of inferentialism.

The theory of inferentialism provides interesting elements for a more detailed understanding of the roles of the learners in the interaction with each other. In particular, it underpins *that,* and *how* the learning of conceptual understanding can effectively be realized in Vision II learning environments. Also the teacher can use the 'giving and asking for reasons' in his or her role in guiding the learning process.

Experimental Work

The importance of experimental work (in the classroom or outside of the school) is an aspect in science education, which should be added to the classification of learning environments. This may also be true for other domains (see for example the Statistics course with the case on growth of fishes in a fish farm (Bakker & Derry, 2011).

Curriculum Representations and Assessment

Another problem that became visible in the analysis of the learning environments in the chapters in this book is the difference between the *design* of a curriculum and the *actual realisation* of it in the classroom. There can be an important difference between the design of a learning environment and the realisation of the design in the classroom. Teachers who make a shift to a knowledge-construction perspective (Vision II) in the learning environment not only have to adopt other learning goals, but also face changes concerning other aspects of the learning environment. Teachers who create a constructivist learning environment such as CBLES, often simultaneously strive to achieve more traditional goals, such as the mastery of fundamental science, and tend to think still along the lines of a transmission model of learning. The tenacity of 'regressing' to the transmission model most likely relates to the current assessment methods that usually reflect (and favour) transmission-type education (Shepard, 2001). If assessment is not in line with the principles of the context-based learning environment, the implicit goals of learning will tend to corrupt the intended learning process as is clearly illustrated in Chapter 12. New learning environments need the replacement of traditional assessment methods as argued by Van Hout-Wolters (2000).

Classifications of learning environments in CBLES should therefore provide information about the curriculum actually realised in classroom, and provide information about the assessment and it's alignment to the learning goals; cognitive, affective as well as metacognitive (e.g. learning).

CBLES is a drastic change in the learning environment when compared with the traditional curricula in science. The drastic change not only involves a change in goals, content and emphases, but also in learning activities, teacher roles and student roles, and the content and methods of assessment. In this innovation process also the meaning of 'context' changes. The complex design trajectory between the ideal or intended curriculum, the designed curriculum, the perceived curriculum and the attained curriculum observed in classroom, will deviate from the initial ideas (Chapter 12). This process is also influenced by the national or state examinations and standards. Nevertheless, this is illustrated by Vos et al. for the Netherlands and Germany alike (Chapter 8, this book). Summarizing, this means that in order to evaluate the effect of the various CBLES, we will have to wait for actual outcomes: the learning effects and the curriculum as perceived by teachers and learners.

COMPETENCIES OF TEACHERS AND THEIR PROFESSIONAL DEVELOPMENT

Section II (Chapters 6–12) of this volume has presented research from the diverse landscape of teachers creating context-based learning environments in science. A reflection upon the various chapters gives an opportunity to further explore the dimensions of variability of context-based learning environments, and on the demands that the creation of context-based learning environments imposes on teachers. The studies provide ways in which teachers can be supported in creating context-based learning environments.

In the first part of this concluding chapter the focus was on an overarching framework for the analysis of learning environments in context-based science education (CBLES). From this analysis and the supporting literature it is clear that the role of the teacher in CBLES is quite different from the role of the teacher in traditional science education. The framework presented earlier also helps to structure the reflections on these differences and the professional development to accommodate these differences.

In chapter 1 we described a provisional list of required teaching competencies:

- to understand the context at hand,
- to be able to handle contexts in educational practice adequately,
- to be willing and able to focus their lessons on more than just formal science knowledge,
- to be able to coach and (help) regulate the learning process of student that have a relative freedom on what, when and how to learn,
- to be able to flexible adapt the learning environment as to facilitate the various learning trajectories taken (redesign),
- to be able and willing to compose adequate tests for fair and complete assessment, and
- to be able and willing to advocate and demonstrate the context-based approach to their colleagues and within their schools.

So far, the reflection in this chapter has led to a precise description of the variety amongst CBLES, focussing on the degree to which CBLES attempts to implement Vision II in particular. We will now reflect on the implications for teachers.

Regarding the goals of science learning, the classification scheme presented distinguishes new kinds of learning outcomes, such as affective and metacognitive outcomes and other emphases than Fundamental Science. These other goals and emphases have substantial implications for the role of the teachers. Vos et al. (Chapter 8, this book) provided an analytical framework for the levels of thinking and acting of teachers, starting from the intended curriculum down to the operational curriculum in the classroom in order to analyse the fostering and hindering factors in the implementation of CBLES as intended by the designers. It is known that teacher's values and beliefs influence this implementation, consciously and unconsciously. "Teaching practices are shaped and framed by teacher's beliefs, especially their beliefs about learning, teaching and the nature and purpose of whatever they are teaching […] Teacher's beliefs will filter their interpretations of the intended curriculum, as well as their ultimate implementation of the curriculum in classroom practice" (Vos et al., p. 143). From their studies the authors draw the conclusion that value congruence is an important factor for sustainable change in classroom practice.

The introduction of CBLES requires teachers to reconceptualise their thinking about teaching their subject. A new curriculum emphasis may be needed. This process involving the goals and emphases of science education is complex and takes time and effort of the teachers, also because it involves their feelings, values and conceptions of their role as teacher. While they are developing their thinking about teaching, they mostly will be busy with their teaching in the traditional curriculum and cannot change this bit-by-bit because the change requires a fundamentally new conceptualization, regarding the goals, roles and activities of teaching CBLES. So, there is a great need for professional development programmes that support teachers in this change (Stolk et al., this book; Dolfing, 2013). Of course, other factors in the innovation process are needed as well, such as national curriculum goals, standards and exams, materials from publishers and research on effective learning environments.

In a study on the professional development of science teachers for CBLES, Dolfing (2013) focused on the support of teachers in their sense-making of three activities in teaching context-based education: setting a context in class, performing the new teaching role, and teaching the new content. Teachers participated in a professional development programme (with a framework, that was adapted from the framework that Stolk et al. described in this book), to accommodate their personal frame of reference regarding the three activities (Dolfing, 2013). Teachers' sense-making during the programme, was analysed in terms of the categories 'assimilation, accommodation, toleration and distantiation'. The results showed that the professional development programme led to teachers' accommodation of all three aspects. The influence of an additional phase of problem analysis in the framework to facilitate teachers' sense-making in teaching the new content appeared effective.

The study by Dolfing focused on the important phases in the development of the personal and professional expertise, including the domain-specific expertise (in this case the macro-meso-micro thinking with structure-property relations, a new subject in CBLES). The study also shows that there is still a long and quite difficult way to go before the teachers have assimilated their new roles and can fully use their new expertise in the learning environment of CBLES.

In the German project on CBLES a symbiotic strategy was chosen to implement the idea of Chemie im Kontext (ChiK) in schools. This strategy combines successful elements of the top-down and bottom-up approaches used so far (Di Fuccia & Ralle, this book). Design of new materials is combined with professional development in local learning communities of teachers in the innovation process of CBLES. This strategy can give teachers a deeper understanding and more ownership of CBLES. In the Netherlands this strategy is also used successfully on a large scale in the introduction of CBLES (Coenders, Ter Louw, Dijkstra, & Pieters, 2010). In the same perspective Bulte and Seller suggest scaling up CBLES innovation with interconnected professional learning communities as the basic unit (Bulte & Seller, 2010). The results of the studies by De Putter-Smits et al. (this book) and Ottevanger et al. (this book) support the need for large-scale professional development of teachers in order to implement CBLES learning environments in all its aspects as intended. The conclusion of this part of the reflection on the chapters in this book is that professional development indeed may be the most important and the most difficult part of the process of teachers creating context-based learning environments in science, as was the focus in the title of this book.

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