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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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.

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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.