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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.

REFERENCES

Aikenhead, G. (2007, May). Expanding the research agenda for scientific literacy. In C. Linder, L. Östman, & P. O. Wickman (Eds.), *Promoting scientific literacy: Science education research in transaction, Proceedings of the Linnaeus Tercentenary Symposium at Uppsala University, Uppsala, Sweden*. Uppsala, Sweden: Geotryckeriet.

Bakker, A., & Derry, J. (2011). Lessons from inferentialism for statistics education. *Mathematical Thinking and Learning, 13*, 15–26.

Brandom, R. B. (1994). *Making it explicit.* Cambridge, MA: Harvard University Press.

Brandom, R. B. (2000). *Articulating reasons: An introduction to inferentialism*. Cambridge, MA: Harvard University Press.

Bulte, A. M. W., Westbroek, H. B., de Jong, O., & Pilot, A. (2006). A research approach to designing chemistry education using authentic practices as contexts. *International Journal of Science Education, 28*(9), 1063–1086.

Bulte, A. M. W., & Seller, F. (2010) Making an innovation grow, on the shared learning within and between communities. In C. Linder, L. Ostman, D. A. Roberts, P. O. Wickman, G. Ericksen, & A. Mackinnon (Eds.), *Exploring the landscape of scientific literacy*. Oxford: Routledge.

Coenders, F., Terlouw, C., Dijkstra, S., & Pieters, J. (2010). The effects of the design and development of a chemistry curriculum reform on teachers' professional growth: A case study. *Journal of Science Teacher Education*, *21*(5), 535–557.

De Kock, A., Sleegers, P., & Voeten, M. J. M. (2004). New learning and the classification of learning environments in secondary education. *Review of Educational Research, 74*(2), 141–170.

Dolfing, R. (2013). *Teachers' professional development in context-based chemistry education, strategies to support teachers in developing domain-specific expertise* (Doctoral dissertation). Utrecht University, Utrecht.

Driscoll, M. P. (2000). *Psychology of learning for instruction* (2nd ed.). Boston, MA: Allyn & Bacon.

Duranti, A., & Goodwin, C. (Eds.). (1992). *Rethinking context: Language as an interactive phenomenon.* Cambridge, UK: Cambridge University Press.

Engeström, Y. (1987). *Learning by expanding: An activity-theoretical approach to developmental research*. Helsinki, Finland: Orienta-konsultit.

Gilbert, J. K. (2006). On the nature of "context" in chemical education. *International Journal of Science Education, 28*(9), 957–976.

Gilbert, J. K., Bulte, A. M. W., & Pilot, A. (2011). Concept development and transfer in context-based science education. *International Journal of Science Education, 33*(6), 817–837.

Jonassen, D. H., & Rohrer-Murphy, L. (1999). Activity theory as a framework for designing constructivist learning environments. *Educational Technology Research and Design, 47*(1), 61–79.

Klaassen, C. W. J. M. (1995). *A problem-posing approach to teaching the topic of radioactivity* (Doctoral dissertation). Utrecht University, CD Bèta, Utrecht, The Netherlands.

Land, S. M., & Hannafin, M. J. (2000). Student centered learning environments. In D. H. Jonassen & S. M. Land (Eds.), *Theoretical foundations of learning environments* (pp. 1–23). Mahwah, NJ: Lawrence Erlbaum.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation.* Cambridge, UK: Cambridge University Press.

Layton, D. (1993). *Technology's challenge to science education.* Buckingham, UK: Open University Press.

Leontev, A. N. (1978). *Activity, consciousness and personality.* Englewood Cliffs, NJ: Prentice-Hall, Inc.

National Science Foundation. (1983). *Educating Americans for the twenty first century, Report of the National Science Board on Pre-College Education in Mathematics, Science and Technology*. Washington, DC: National Science Foundation.

Prins, G. T., Bulte, A. M. W., & Pilot, A. (2016). An activity-based instructional framework for transforming authentic modelling practices into meaningful contexts for learning in science education. *Science Education*. doi:10.1002/sce.21247

Roberts, D. A. (2007). Scientific literacy/science literacy. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 729–780). New York, NY: Routledge.

Roth, W. -M. (1996). Where is the context in contextual word problems? Mathematical practices and products in Grade 8 students' answers to story problems. *Cognition and Instruction, 14*, 487–527.

Shepard, L. A. (2001). The role of classroom assessment in teaching and learning. In V. Richardson (Ed.), *Handbook of research on teaching* (pp. 1066–1101). Washington, DC: American Education Research Association.

Simons, P. R. J. (2000). Towards a constructivistic theory of self-directed learning. In G. A. Straka (Ed.), *Conceptions of self-directed learning: Theoretical and conceptional considerations* (pp. 155–169). Münster, Germany: Waxmann.

Simons, P. R. J., Van der Linden, J., & Duffy, T. (Eds.). (2000). *New learning.* Dordrecht, The Netherlands: Kluwer Academic Publishers.

Van Aalsvoort, J. (2004). Activity theory as a tool to address the problem of chemistry's lack of relevance in secondary school chemical education. *International Journal of Science Education, 26*(13), 1635–1651.

Van Oers, B. (1998). From context to decontextualizing. *Learning and Instruction, 8*(6), 473–488.

Van Hout-Wolters, B. (2000). Assessing active self-directed learning. In R. J. Simons, J. van der Linden, & T. Duffy (Eds.), *New learning* (pp. 21–36). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Vygotsky, L. S. (1998). *The collected works of L. S. Vygotsky, Volume 5, child psychology* (R. W. Reiber, Ed.). New York, NY: Plenum.

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