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An Analysis of Teaching Competence in Science Teachers Involved in the Design of Context-based Curriculum Materials

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The committees for the current Dutch context-based innovation in secondary science education employed teachers to design context-based curriculum materials. A study on the learning of science teachers in design teams for context-based curriculum materials is presented in this paper. In a correlation study, teachers with ($n = 25$ and 840 students) and without ($n = 8$ and 184 students) context-based curriculum material design experience were compared on context-based competence. Context-based competence comprises context handling, regulation, emphasis, design, and school innovation. Context-based teaching competence was mapped using both qualitative and quantitative research methods in a composite instrument. Due to the differences in design team set-up for different science subjects, teachers with design experience from different science subjects were also compared on their context-based competence. It was found that teachers with design experience showed more context-based competence than their non-designing colleagues. Furthermore, teachers designing for biology showed more context-based competence than their peers from other science subjects.

Keywords: *Context-based learning; Quantitative research; Teacher development*

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Introduction

A trend in high-school chemistry education in many countries is to switch to a context-based approach, due to the falling number of students enrolling in scientific further education (Bennett, Lubben, & Hogarth, 2007). It is believed that context-based education motivates students more for the subject, thus leading to a larger number of students continuing in scientific further education (Gilbert, 2006).

Science teachers have been involved in the design of curriculum materials in the context-based innovation in the science subjects in the UK, Germany, and the Netherlands. The reasons for this involvement are the expectation that teachers will be more willing to accept the innovation when they have been a part of it (Fullan, 1994) and to make the curriculum materials well suited to classroom practice (Bennett & Lubben, 2006).

This paper centres on the question: what have science teachers who were involved in the design of context-based curriculum materials learned from that experience?

The majority of publications on context-based science education seem to concern high-school chemistry. In this study, the focus is on the science subjects biology, chemistry, physics and advanced science, mathematics, and technology (ASMaT), since the Dutch curriculum innovations for these subjects have jointly chosen to use a context-based approach. In the remainder of this paper, the term *science* is used to refer to these four high-school science subjects.

Theory

Context-based Education

In a review of research on context-based education Bennett et al. (2007) define this approach as:

> 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. (p. 348)

An important accompanying element of context-based education described by Gilbert (2006) and by Parchmann et al. (2006) is active learning. This requires students to have a sense of ownership of the subject and to be responsible for their own learning. The combination of active learning and the use of contexts is consistent with the constructivist view of learning underlying context-based education (Gilbert, 2006).

In a previous study, a context-based *science* education has been defined as an approach in which contexts that are meaningful to the student are used as the starting point for the learning of scientific concepts, students are responsible for their own learning (active learning) in an environment that can be organised by them and their teacher to their needs, interacting with other science subjects or outside-school organisations where appropriate (De Putter-Smits, Taconis, & Jochems, in press a, in press b). Teachers should be able to create a learning environment that contains these elements of context-based education. In the following paragraphs, such teacher competence in context-based education is described.

Context handling. In context-based education, teachers can be confronted with materials that contain contexts they are unfamiliar with. Hence, they are required to be capable to familiarise themselves with any context expressed in curriculum material and to be able to present and clarify it to the students. The context is to be used as a starting point for learning scientific concepts on a need-to-know basis (Parchmann et al., 2006). This differs from traditional education where the concepts are of foremost importance and are usually explained first before examples and applications are discussed. The required teacher attitude towards contexts is phrased by Gilbert (2006) as: '[...], the teacher needs to bring together the socially accepted attributes of a context and the attributes of a context as far as these are recognised from the perspective of the students' (p. 965). Teachers have to be aware of the need for concept transfer (to other contexts) (Van Oers, 1998). The context should cause a need for students to explore and learn concepts and to apply them to different situations. This teacher competence (context, concept, and re-contextualising) is referred to as *context handling*.

Regulation. In traditional science education, the responsibility for learning rests mainly with the teacher described by Vermunt and Verloop (1999) as 'strong teacher regulation'. Friction between student learning and teacher activities can for instance arise when loose regulative student materials are taught by teachers only experienced in strong regulative teaching activities (Vermunt & Verloop, 1999). In context-based education, the responsibility for learning is shared by teacher and learner, requiring teachers to change their teaching activities into shared or loose control strategies. Teachers should be competent in handling the kind of activities required, i.e. to guide rather than control the learning process of the students. This teacher competence is referred to as *regulation*.

Emphasis. Using contexts as a starting point for learning corresponds to a different teaching emphasis as compared to traditional science education (Gilbert, 2006). Emphasis has been defined thus by Roberts (1982):

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

Generalising the emphases described by Van Driel, Bulte, and Verloop (2005) from chemistry to science, three different emphases can be identified:

> a fundamental science (FS) emphasis where theoretical notions are taught first because it is believed that such notions later on can provide a basis for understanding the natural world, and are needed for the students' future education; a knowledge development in science (KDS) emphasis where students should learn how knowledge in science is

> developed in socio-historical contexts, so that they learn to see science as a culturally determined system of knowledge, which is constantly developing; and a science, technology and society (STS) emphasis where students should learn to communicate and make decisions about social issues involving scientific aspects. (De Putter-Smits, Taconis, Jochems, & Van Driel, 2011, p. 36)

A science, technology, and science (STS) or knowledge development in science (KDS) teaching emphasis is a competence referred to as *emphasis*.

Design. Seen from a constructivist perspective, the available context-based materials are not immediately suited to every classroom or to the needs of the students and teachers. Besides this, the more active role for the student embedded in the context-based curriculum material requires activities such as experiments that put a demand on time tables. The necessity for the teachers to redesign the material to the schools' facilities arises, since it is unlikely that all schools have the opportunity to meet the exact requirements of the context-based materials, e.g. computer and experimentation facilities.

Student-regulated learning can lead to unpredictable learning demands, causing the teachers to redesign education on the spot, including new lesson plans, curriculum materials, experiments, and so on. Teachers are therefore expected to (re-)'design' the context-based material. Hence, it is expected that the educational *design* teacher competence is in demand in context-based education and might be new to traditional teachers.

School innovation. Teachers have to cooperate with colleagues of their subject field and even possibly across science subjects to implement the context-based approach, in order to create coherence in the science curricula. An innovation cannot succeed if it is only supported by isolated teachers (Fullan, 1994). The Dutch innovation committees expect teachers to be representatives of the innovation in their schools (Boersma et al., 2007, Steering Committee Advanced Science, Mathematics and Technology, 2008). An increased belief and wish to collaborate within schools is observed among teachers involved in developing curriculum materials for 'Chemie im Kontext' (ChiK) in a study into the learning effects. These teachers are also likely to be involved in collaborative relationships in their own schools (Gräsel, Fussangel, & Parchmann, 2006). This teacher competence is referred to as *school innovation*.

The five teacher competences identified as important for teaching context-based education have been described. They are: context-handling, regulation, emphasis, design, and school innovation.

Learning Through the Design of Materials

There are several empirical studies in which teachers were involved in the design of study materials (cf. Hoogveld, Paas, & Jochems, 2005; Linn, Clark, & Slotta, 2003). However, most focus on the quality of the material and/or the results of student learning. Only few studies have been concerned with the learning of *science teachers* involved in the design of curriculum material.

Design of curriculum materials is described as an important activity for teacher learning (Borko, Jacobs, & Koellner, 2010; Deketelaere & Kelchtermans, 1996). The reasoning behind this is that teacher learning benefits from the proximity of the design of curriculum materials to the actual teaching practice, resulting in a 'sense of ownership' (Borko et al., 2010). In combination with the actual teaching of the curriculum materials made, the learning is expected to be more profound (Deketelaere & Kelchtermans, 1996). Deketelaere and Kelchtermans (1996) go on to conclude that the combination of teachers and university experts in curriculum design teams leads to not only better materials, but also to more profound teacher learning.

Changes in teaching practice, which were the result of science teachers being involved in the design of context-based curriculum material, were reported in three cases. Parchmann et al. (2006) reported a change in the context-handling competence of chemistry teachers; Mikelskis-Seifert, Bell, and Duit (2007) reported a change in the regulation competence of physics teachers; Gräsel et al. (2006) reported a change in the school innovation competence of chemistry teachers. A change in teacher competence in creating a context-based learning environment can thus be expected of teachers working in context-based curriculum design teams.

Background to This Study: The Dutch context-based innovation

The Dutch Ministry of Education, Culture and Science has instituted committees for the high-school subjects biology, chemistry, physics, and ASMaT with the assignment to develop new science curricula. The new curricula should cover modern science, relieve the current overloaded curricula and interest more students in choosing science in further studies (cf. Kuiper, Folmer, Ottevanger, & Bruning, 2009a). These science curricula were meant for years 10 and 11 of senior general secondary education and for years 10–12 of pre-university education. The subject ASMaT differs from the other science subjects in that it is a newly created school subject for which, up to then, no curriculum or learning goal had been designed (Steering Committee Advanced Science, Mathematics and Technology, 2008). All committees decide to use a form of context-based education (Boersma, Eijkelhof, Van Koten, Siersma, & Van Weert, 2006) to counter the falling popularity of science subjects among students, also visible in the Netherlands (Bulte et al., 2000).

The innovation committees were committed not just to presenting a 'list of concepts' to the Ministry of Education, Culture and Science, but to providing a tried and working curriculum (cf Driessen & Meinema, 2003). To this end, they enlisted teachers to develop aspects of the context-based curriculum, i.e. curriculum modules, textbooks, workbooks, and worksheets for experiments in cooperation with experts on the pedagogy of science. Each of the novel science curricula was tested in schools throughout the Netherlands for three years, including an adapted national final exam.

However, all committees differed in their explanation of context-based education, and hence in the guidelines presented to the design teams. They also differed in the set-up and organisation of the respective curriculum design teams and in the available funding (Boersma et al., 2007; Commissie Vernieuwing Natuurkunde Onderwijs HAVO/VWO [Innovation Committee High School Physics Education], 2006; Driessen & Meinema, 2003; Steering Committee Advanced Science, Mathematics and Technology, 2008). The differences between the teams from different science subjects will be discussed in some detail, since this study concerns the learning of teachers in the various curriculum design teams. An overview of the characteristics of the different design teams is provided in Table 1.

The biology innovation committee chose a strategy where one or more teachers per school would design curriculum modules and try them in class and improve the module where necessary. In all, seven schools were selected where teachers made the curriculum modules, sharing them with the other schools. In practice, this meant in some schools one teacher working on his own, testing his own material; in other schools there were more teachers involved in the design and try-out of the curriculum modules. The schools were funded to provide the designing teacher with time for the curriculum design activity.

The chemistry innovation committee's strategy was to 'let all flowers blossom'. Besides the official start document (Driessen & Meinema, 2003), no other guidelines were provided. Teachers, experts, and known curriculum designers were asked to

Table 1. Overview of design team characteristics for the different subjects

Start	ASMaT (2006)	Biology (2006)	Chemistry (2003)	Physics (2006)
Design team				
Finance	Available	Available	Llittle: none	Little: none
Number of teachers	Minimum of 4	1 (one of the teams has more)	Varies 1–6	1–3
From number of schools	2	1	1–5	Up to 3
Experts	Available	Available to 2 teams	0–6	1–5
Number of teams	>50	14 (from 7 different schools)	50–100	10
Instructions				
Design process	Available	None	None	Model
Context-based education	Not strict	None	not strict	Not strict
Materials				
Test method	Other school	Own school	Varies	Other school
Controlled by committee	Certificate	Partly	Partly	Yes
Published by committee	Website	DVD and website	Website	DVD and website

make curriculum materials. Little funds were available for this endeavour from the innovation committee; however, an industrial lobby also involved itself, providing some funds for teachers and educational experts to design curriculum materials in cooperation with experts from industry on modern applications of chemistry. The material designed for the context-based chemistry innovation varies in the interpretation of context-based education and in the concepts covered in each curriculum module. The committee organised the completed modules into four major learning continuity pathways (roughly corresponding to the different interpretations of context-based education) to be able to test the curriculum in a national exam.

The physics innovation committee appointed volunteering teachers and combined them with experts to make curriculum modules on certain concepts. The teams consisted of one teacher to design the module, assisted by one or more teachers to comment and try the module, an expert on the pedagogy of physics and a content expert. The designer-teacher was provided with exemplary curriculum material from other countries and a design model (the generic analysis, design, development, implementation, and evaluation model often referred to as ADDIE). As it turned out, the quality and progress of the work varied, inducing the committee to change the approach. The most promising designer-teachers were asked to finish all the curriculum materials made so far with the help of experts on the pedagogy of physics (approximately eight teams of two people). An editor was hired to create coherence in the series of modules that would cover the curriculum. The curriculum modules were tested in different schools from those where the designer-teachers worked.

ASMaT was a new subject, for which no materials were available. This gave the teachers even more freedom in designing their own curriculum and materials, drawing even stronger on the competence of 'design'. The ASMaT committee had relatively large funds available for their endeavour to design a curriculum, having corresponding materials made and having the curriculum modules tried in classrooms. Schools were invited to find a partner-school to make an ASMaT module in return for funding. The schools were required to submit a proposal along strict guidelines, describing details on the context chosen, the concepts to be covered and the project planning. Per school two teachers were involved and the committee provided each team with a coach and access to experts on the context chosen. The curriculum modules were tested in a third school before they were finally submitted to the committee, who then certified the module, or altered it using a professional editor as it saw fit.

In this research, active science teachers that have designed curriculum materials for one of the four Dutch innovation committees were studied.

The research questions addressed in this paper were:

(1) What are the context-based teaching competencies of science teachers who have worked in design teams for context-based curriculum materials and can these competencies be attributed to the design team work?
(2) What are the differences in context-based competence of science teachers who designed for different science subjects?

(3) What other (informal) learning do teachers that have worked in context-based curriculum design teams experience?

Research Design

Science teachers from ASMaT, biology, chemistry, and physics were studied on their competence in context-based education to answer the research questions. In the remainder of this paper, science teachers with curriculum design experience for the context-based innovation are referred to as *designers*, as opposed to *non-designers* or *teachers* for those who do not have design experience.

The study is in retrospect since most curriculum design teams have finished their task. Therefore, designers were compared with teachers to evaluate whether there are differences between the two groups. The designers and non-designers were asked to attribute their context-based competence.

Another comparison made was whether there are differences in context-based teaching competence in designers connected to the subject they designed for.

Participants

From the lists of authors of official (approved by the innovation committees) context-based curriculum materials, 50 teachers who were still teaching were approached by phone and email to join this study. Of these teachers, 25 accepted the invitation. From the network of the authors, 50 science teachers without context-based curriculum material design experience were recruited to join the study. Here, eight teachers accepted the invitation. Care was taken that all teachers form a group adequately representing 'Dutch science teachers' with respect to key variables such as experience, education, and subject. No teachers for ASMaT were present in this sample, since ASMaT is a new subject. In Table 2, an overview of the participants is presented.

Instrument

The instrument used to map the context-based competences of the designers and teachers included both qualitative and quantitative research methods. Since this composite instrument was to be used in a Dutch research setting, it was designed and tested

Table 2. Overview of the participants

	ASMaT	Biology	Chemistry	Physics
Designers per subject they designed for	8	5	6	6
Students from designers	243	177	214	206
Teachers per subject they teach	–	4	2	2
Students from participating teachers	–	86	46	52

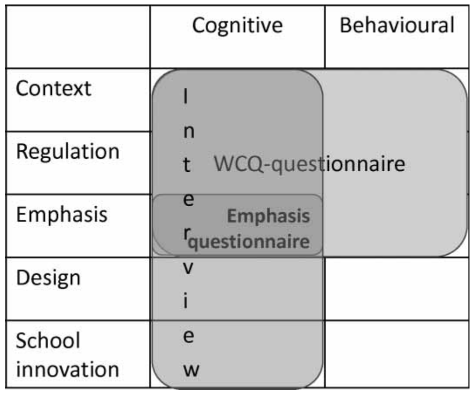

Figure 1. Schematic representation of the instrument used in the study

in the Dutch language. The focus of the instrument was on the context-based learning environment the teachers were able to create, both on the cognitive and the behavioural dimension. The composite instrument provided data that were recalculated into a score for all the context-based competences as presented in the schematic in Figure 1. The components of the instruments and a sample calculation of a competence score are described below.

The reliability and validity of the composite instrument was established in a pilot study (De Putter-Smits, Taconis, & Jochems, 2009). A Cronbach's α of 0.84 was obtained for the total context-based competence scale. The instruments' power to discriminate between teachers with varying backgrounds (predictive validity) was also established in the pilot study (De Putter-Smits et al., in press a).

The WCQ questionnaire consisted of scales from international standard questionnaires such as the WIHIC (Dorman, 2003) and the CLES (Johnson & McClure, 2004). For the Dutch setting, the items were translated. The WCQ was then used in a national study where its validity to measure the context-based learning environment was established (De Putter-Smits et al., in press b). The scale representing the competence of context-handling contained 17 items with a Cronbach's α of 0.91. The scale representing the competence of regulation contained 13 items with a Cronbach's α of 0.85. The scale representing the competence of emphasis contained 12 items with a Cronbach's alpha of 0.83 (De Putter-Smits et al., in press b).

The (originally Dutch) emphasis questionnaire developed by Van Driel et al. (2005) was adapted to represent all science subjects. It was validated among 213 science teachers. Three scales (FS, KDS, and STS) were confirmed with Cronbach's alpha ranging from 0.73 to 0.90 (De Putter-Smits et al., 2011).

The semi-structured interview contained questions on the context-based competences. Answers to interview questions were assessed by two researchers independently using a codebook (Ryan & Bernard, 2000) and scored on a five-point Likert scale. Next, the scores are discussed until full agreement was obtained. For instance, the answer to the question: *What does context-based education entail? – specifically on the context?* was given a five when all the elements of the context-handling competence (see theory section) were present and explained by the participant's answer.

Some interview questions required answers as a percentage, for instance: *Can you indicate on this scale what percentage of control lies with you as a teacher?*

To compensate for the difference in scales, all scores were standardised before proceeding. The *z*-scores per competence were then combined into a score per competence and finally into a total score on the cognitive and on the behavioural dimension. An example of such a calculation for the context-handling competence on the cognitive level is: taking the average of the WCQ average *z*-score on the context-handling scale and the average *z*-score of the interview questions on context handling (two questions).

Analysis

All scores were calculated as indicated in the instrument section. To confirm the reliability of the instrument the Cronbach's α of the items per cognitive and behavioural competency scale was computed.

Next the participants' background characteristics were analysed to ensure the designers and non-designers were comparable for the purpose of this study. Possible influencing background characteristics were identified by correlating them with the context-based competency scores.

To answer the first part of research question one, a *t*-test was performed between the scores of the designers and the scores of the teachers.

To answer the second part of research question one, the participants were asked to attribute their knowledge on context-based education, this being a retrospect study. The answers of the designers to the question: *How did you acquire your knowledge on context-based education?* were analysed. The answers were tallied into six categories, five pre-suggested ones (course or workshop, symposium organised by innovation committee, publication of the innovation committees, design team *work*, through a design team *member*) and one 'other'. These attributions were correlated with the different context-based competence scores to obtain insight into which aspect(s) is most important for learning to teach context-based education, e.g. they attributed their learning to their teacher education, their teaching experience, their curriculum design experience, etc.

The second research question was answered by comparing the scores from the designers per subject they designed for using a Mann–Whitney *U* test.

Where appropriate, qualitative results are provided to illustrate quantitative results.

To answer the third research question all additional mentioned learning experiences, including implicit learning (Eraut, 2004), were analysed by coding the experiences, categorising the codes and identifying themes and relationships among the codes and categories (Miles & Huberman, 1994).

Results

Participant Analysis

The analysis showed that for biology 5 of the possible 14 biology designers and 6 of the 10 physics designers were part of this study. Compared with the number of designers for chemistry and ASMaT in the study (6 and 8 out of an estimated 50–100 designers), the designers for biology and physics in this study were more likely to represent the group of designers for their subject.

Not all designers teach the subject they designed curriculum material for. There were no teachers for the new curricular subject ASMaT in the study.

The 25 designers were compared with 8 non-designers on their context-based education competences. To ensure that the sub-samples were comparable, the teachers' background characteristics were analysed.

A *t*-test confirmed that the non-designers were significantly younger than the designers ($t(31) = -2.16$, $p < 0.05$, $r = 0.36$), although the effect size is medium. However, the differences in teaching experience and teaching qualification between the two groups were not significant. Teachers with more than five years of teaching experience are considered to have developed an expertise in teaching (Berliner, 2001), making the participants comparable in that respect.

A distinguishing characteristic of designers was *holding a relevant additional job*, such as designing study material for universities (10 out of 25) or teaching pedagogy of science to student teachers (11 out of 25). However, further analysis of the data revealed no significant influences of 'additional jobs' on the total context-based competency score.

A further analysis of possible influences was carried out, revealing no further indications of deviations in the sample.

Instrument Analysis

All answers to competency questions were analysed and scored by two researchers working separately, reaching an agreement of 0.80 (Cohen's κ). Next the differing items were discussed until full agreement was obtained.

The competency scale scores were constructed as described in the instrument section out of the standardised score for each item. For each scale of the instrument the Cronbach's α was calculated. The results of the instrument's reliability are depicted in Table 3. The item rest correlations for the cognitive competency scales showed considerable overlap (>0.40), which is expected since these scales together form one total context-based competency scale (De Putter-Smits et al., 2009). School innovation was an exception to this. This was expected since the school innovation competency was designed to measure interactions outside the classroom rather than those related to classroom practice (the other four) (De Putter-Smits et al., in press a).

The behavioural competency scales showed high item rest correlations. This could be an indication that students could not (or were not able to) discriminate among the different teaching competencies within the general context-based competence,

Table 3. Context-based competency scales: reliability

	Cognitive			Behavioural		
Scale	Number of indicators k	α	Item rest correlation	Number of indicators k	α	Item rest correlation
Context handling	9	0.84	0.65	4	0.81	0.84
Regulation	20	0.74	0.64	16	0.83	0.76
Emphasis	41	0.58	0.55	12	0.80	0.90
Design	*2*	*0.68*	0.56	–	–	–
School innovation	4	0.50	0.02	–	–	–
Total score	76	0.71	–	32	0.91	–

whereas the teachers and the researchers could. However, a multi-level analysis in the national study using this part of the composite instrument clearly indicated that the scales are separate, though related as shown in Figure 1 (De Putter-Smits et al., in press b)

The reliability coefficient (Cronbach's α) for the scale 'total score' was found to be 0.78.

Context-based Competency Scores and Context-based Design Experience

The results on the first part of research question one, whether context-based curriculum design experience is an underlying factor of context-based teaching competence are presented below.

The means and standard deviation of the context-based competency scores for all teachers were computed and are shown in Table 4.

A *t*-test (one-tailed) indicated a significant positive difference between designers and non-designers on the total cognitive competency score ($t(31) = 1.95$; $r = 0.39$). For the separate cognitive scales, a positive relation of design team experience with 'context handling' and 'design' was found ($t(31) = 2.60$; $r = 0.52$ and 2.42; $r = 0.45$, respectively). These effect sizes are medium to large (>0.30 is medium; >0.50 is large; Cohen, 1992). For the behavioural scales, no significant result was found.

Knowledge of Context-based Education

The answer to the second part of the first research question on where the designers attributed their knowledge on context-based education to is described next.

A qualitative analysis of the category *other* revealed two extra categories: *a person in the teachers' direct environment* such as a colleague or professional friend and *internet documentation and books*.

Of the five pre-suggested sources and the two *other* sources of knowledge on context-based education named by the designers, *design team work* and *through a design team member* correlated significantly with the context-based competence

Table 4. Context-based competency scores of designers and non-designers and significant differences between the two groups

	Cognitive				Behavioural			
	Designers		Non-designers		Designers		Non-designers	
Scale	M	sd	M	sd	M	Sd	M	sd
Context handling	0.17**	0.78	−0.58	0.39	0.01	1.08	−0.13	0.72
Regulation	0.03	0.70	−0.06	0.69	−0.15	0.82	0.38	0.64
Emphasis	0.07	0.70	−0.17	0.83	−0.03	1.03	0.09	0.43
Design	0.19**	0.83	−0.60	0.73	–	–	–	–
School innovation	−0.10	0.75	−0.18	0.48	–	–	–	–
Total score	0.07*	0.51	−0.32	0.41	−0.06	0.92	0.11	0.54
N	25		8		25		8	

*Significant with $p < 0.05$.

**Significant with $p < 0.01$.

scores. These are shown in Table 5. None of the other categories correlated significantly with the context-based competencies, official meetings, or publications of the innovation committees included.

From the analyses of the interviews, it was apparent that many designers had followed one or more official symposia organised by the respective innovation committees. Although they all indicated they had been to these symposia, they also almost all indicated that their knowledge on context-based education was not influenced by them. According to the designers, making the context-based materials, discussing context-based education with peers and experts during this process and other occasions, as well as trying them in class gave them the knowledge they have on context-based education. Or as they put it: 'made it clear how context-based education actually *works* (quote from semi-structured interview).

Table 5. Correlating sources for knowledge on context-based education with context-based teaching competency scores for designers ($n = 25$)

	Design team work		Through design team member
Scale	Cognitive	Behavioural	Cognitive
Context handling	0.50*		
Regulation	0.47*		
Emphasis	0.41*	0.44*	0.41*
Design			
School innovation	0.43*		
Total score	0.61**		

*Correlation is significant at the 0.05 level (two-tailed).

**Correlation is significant at the 0.01 level (two-tailed).

Context-based Competency Scores and Design Experience per Science Subject Designed for

The results to the second research question on the differences in teacher competence between *science subjects* teachers have designed for are described below.

The means and standard deviations of the context-based competence scores per subject designed for are provided in Table 6. A Mann–Whitney *U* test revealed significant positive differences on the cognitive context-based competence scores for designers for biology and chemistry. Negative significant differences were found for designers for ASMaT. Other *U*-values were not significant.

During the interview, four of the designers admitted they had only joined the ASMaT design team because the school they worked for required it of them. When the project was finished, they resumed their usual teaching practice, where, according to them, the ASMaT experience had no relevance. When asked whether they did not feel inclined to look at the innovations that are taking place in their usual teaching field, the answers of the designers varied from: *Currently I work with children with autism spectrum disorder. Context-education is not suitable to their needs* to *I am a very good teacher, my students tell me and I believe the classical way of teaching suits me and them best* or *I am interested but cautious. I am working on my higher teaching qualification, I am the school's IT man, so I won't be a frontrunner on this one*, and *In our school classical teaching is advertised both to new teachers such as myself as to the outside world: we are an old-fashioned good school* (teacher remarks during semi-structured interview).

Table 6. Context-based competency scores per science subject designed for and significant differences comparing one subject to all others

	ASMaT		Biology		Chemistry		Physics	
n	8		5		6		6	
Scale	M	sd	M	sd	M	sd	M	sd
Cognitive								
Context handling	−0.36*	0.87	0.80*	0.27	0.37	0.57	0.15	0.77
Regulation	−0.50**	0.69	0.55*	0.35	0.42	0.39	−0.10	0.69
Emphasis	−0.47	0.97	0.26	0.37	0.56*	0.37	0.12	0.20
Design	−0.40*	0.77	0.92*	0.50	0.59	0.50	−0.03	0.85
School innovation	−0.21	0.68	0.29	1.06	−0.28	0.72	−0.10	0.64
Total score	−0.39**	0.53	0.57**	0.12	0.33	0.34	0.01	0.30
Behavioural								
Context handling	−0.19	1.06	0.41	1.13	−0.03	0.91	−0.32	1.41
Regulation	−0.48	0.41	0.31*	0.55	0.07	0.79	−0.31	1.29
Emphasis	−0.31	0.83	0.51	0.99	−0.02	0.68	−0.14	1.56
Total score	−0.33	0.66	0.41	0.84	0.01	0.76	−0.16	1.40

*Significant with $p < 0.05$.

**Significant with $p < 0.01$.

Other Teacher Learning in Design Teams

During the semi-structured interview, all designers were asked what other learning experience they had during the design process that had not been covered by earlier questions. From the qualitative analysis of the answers, four categories of learning were identified: elements of context-based education, not previously described in the theory section, the technical part of the writing process, learning about the context-based innovation at a macro level, and learning about personal abilities.

Eight teachers included other elements of context-based education than was defined specifically in the theory section above. One teacher added to the context definition by stating that: *The purpose of experiments has changed from explanation of the theory to the practical purpose of the theory.* Another teacher depreciated the context element by stating that: *Each paragraph now starts with a context before going into theory.*

On the regulative implications of context-based education, six teachers added more specifics. Two teachers added *learning by inquiry* as specific to context-based education, two teachers added that the test methods are different and more diverse in context-based education, one teacher added that students should learn by using the generic ADDIE design model (analysis, design, development, implement, evaluation, used for education among others by Plomp (1982)) and one teacher referred to context-based education as *girl-oriented learning*.

Examples of learning about the technical part of the writing process reported by the teachers were: *Working with a predefined structure is important*, *Writing means deleting text*, *I learned how to handle computer viruses*, *When working in a team make solid agreements and keep each other to these agreements*, and *Writing takes up a lot of time*.

Examples of learning on the innovation at a macro level were: *The method the committee uses to develop the new curriculum does not help nationwide integration* and *My frame of reference for the purposes of my science subject outside the classroom had broadened*.

Examples of a personal ability learning experience were: *I have discovered my own creativity; what I am good at as a writer* and *Personally, I now have more appreciation for material colleagues have made*.

Conclusions and Discussion

The designers and non-designers in the sample were found to be comparable on the average years of teaching experience and the lack of influences of variables such as ‘having an additional job in the pedagogy of science’.

From the reliability data (Table 3), it could be concluded that the instrument performs well.

RQ1

From the results, it could be concluded that the context-based teaching competences ‘context handling’ and ‘design’ are significantly more developed in designers than in non-designers. For the other context-based competences, no significant differences between designers and non-designers were found.

Higher context-based teaching competence was found for designers who attributed their knowledge of context-based education to having worked in a context-based design team. It could also be concluded that context-based teaching competence in context-based education is not related to having read publications from the innovation committees or having attended official symposia (organised by the innovation committees). The conclusion on the latter is not surprising since it is known that single-day workshops are ineffective in changing teaching practice (cf. Borko & Putnam, 1996).

Combining the result for research question one, the process of designing context-based teaching materials appears to be a powerful source to develop the context-based teaching competencies. This result concurs with the conclusion Coenders draws in his case study of teachers' professional growth during the development of context-based chemistry materials: 'involvement in the development process of innovative material is crucial for teacher learning' (Coenders, 2010, p. 150).

While various competencies were found to correlate significantly with design experience at a cognitive level, this was not the case at the behavioural level, which is not unusual in learning environment research. It is suggested that students might be unable to discriminate between the different teaching competencies. Though there is a significant correlation of design team membership with classroom context-based competencies at a cognitive level, and in the teachers self-perception of classroom practice, this might not be recognised by their students and thus not appear on the behavioural level with the instrument (student opinion only). Another explanation might be that the designers have not yet learned enough for the effect to be visible in their classroom. In a German study, physics teachers were found to have changed their teaching practice towards context-based education after three years of designing and teaching context-based curriculum materials (Mikelskis-Seifert et al., 2007).

RQ2

It could be concluded from the results on the second research question that the subject the teacher has designed for is related to the level of context-based teaching competence. This result could be explained by the nature of the science subject itself, by the set-up of the various design teams or by the sample of designers in this study.

Biology designers showed more cognitive context-based competence than the other designers, with context handling, regulation and design as underlying competencies. On the behavioural competency scales, biology designers showed more competence on regulation. Explanations could be sought in the more contextual nature of biology (in the Netherlands) as a subject, but that would not explain why the regulation and design competence were also significantly higher.

Another explanation might be found in the set-up of the biology design teams. This group of designers has the most experience in designing material since they needed to design an entire (three-year) curriculum for their own classrooms, preparing their students for context-based national exams. They were also given time (i.e. money) to work on materials for this entire new curriculum. In general, the *active learning*, i.e. the design of context-based curriculum materials and teaching using these materials, and *content related* nature, i.e. teaching biology to their own students in a different way, of the work the biology designers have undertaken, are known to be vital ingredients for successful teacher professional development (cf. Borko et al., 2010). This could explain why the biology designers in this study score higher on context-based competence.

Half of all context-based biology designers in the Netherlands participated in this research. This means our results were representative for the biology designers in the current innovation. This strongly indicated that for the biology innovation the cognitive teaching competencies context handling, regulation and design, and the behavioural teaching competency regulation were effectively strengthened by the teachers' design experience.

ASMaT designers scored significantly lower than the other designers on context-based competence. The goal of ASMaT was to go scientifically deeper into a subject of interest to the student, for instance, how to construct a zero-energy house. This may require a learning of scientific concepts that goes beyond the expertise of the teacher, which in turn causes them to resort to traditional teaching.

Another explanation could be that not all teachers volunteered for designing curriculum modules. This could lead to a situation where, as soon as the task was over, they resumed business as usual.

Another possible explanation is the fact that five of the eight designers in this sample do not teach using their own context-based materials or any other context-based material. This means that as a group they have not had the same opportunities as other designers to practice context-based competence in class. The lack of opportunity to use the innovative material in their classrooms hinders their professional development towards context-based education, as is suggested by the work of Coenders (2010). It certainly hinders them to *show* their context-based competence.

There have been more than 100 ASMaT curriculum designers. The results for the eight designers in our study might not be representative for all ASMaT designers.

Chemistry designers had a significantly higher cognitive emphasis teaching competence compared with the other designers. This could be explained by the strong focus on KDS teaching emphasis in the Netherlands that was advocated by both the current and the previous innovation committee. From the 1980s onward, an innovation in high-school chemistry is ongoing that introduced experiments and explanations for phenomena into the chemistry curriculum (Hondebrink, 1987). Compared with the other designers no other significant differences in context-based competencies were found, indicating that designing chemistry materials themselves do not lead to increased context-based competence. The set-up for the Dutch chemistry design teams varied widely, making it difficult to generalise the results. Also there have been more than 100 chemistry curriculum designers. The results for the six designers in our study might not be representative for all chemistry designers.

Designers who made material for *physics* did not show any significant differences from the other designers. Their context-based competency scores were low compared with chemistry and biology designers. In the Netherlands, a prior innovation has introduced contexts to learning physics (Eijkelhof *et al.*, 1986). Although teaching methods now include the application of physics concepts, the teaching is generally traditional. This could explain the result found for physics designers. The design teams did focus on a single writer; however, the try-out of the materials was not usually in the designers own classroom, hindering the before-mentioned active learning, which might explain the result.

The designers in this study were representative of the physics designers in the sense that 6 of the 10 main designers participated. It could be concluded that designing context-based materials for physics did not lead to context-based teaching competence. This is in line with the conclusions in the evaluation study of Kuiper, Folmer, Ottevanger, and Bruning (2009b) that the innovative material for physics is not recognised by teachers as representing a new concept of education. In popular debates between pro-innovation and contra-innovation physics teachers and committee members, it was often stressed that no 'state-directed pedagogy' should be enforced (cf. Van Weert & Pieters, 2009). The apparent non-professionalising of physics designers towards context-based education could thus be explained.

Another factor influencing designers in general could be that for many the step to switch to context-based teaching is blocked by their fear of not preparing their students adequately for the national exams (George & Lubben, 2002). Only the schools involved in the context-based national exam trial could request context-based national exams.

RQ3

Other learning included possible additions to context-based competences. *Learning by inquiry* and the use of a specific strategy such as the *ADDIE model* could be categorised under the *regulation* competency, since this kind of learning activity requires students to have more control over their learning process (Bateman, 1990).

Different test methods are mentioned in professional publications for ChiK in Germany, where teachers are handed tools to change test methods when teaching Chemie im Kontext (Nentwig, Christiansen, & Steinhoff, 2004). Context-based testing methods could therefore be added to the competence of *regulation*.

The remark that context-based education is more suitable for girls has been commented on in literature by Bennett et al. (2007) who concluded in their review of 17 experimental studies that both boys and girls showed a more positive attitude towards science when studying the subject with a context-based approach. *Girl-oriented* will therefore not be added as a possible context-based teaching competence.

The other learning reported by the designers was mainly related to the *work* of the team. Two other categories of informal learning were identified: acquiring a view at a macro level on the innovation and personal abilities.

General Impact and Future Research

From this research, it could be concluded that teachers working in design teams for context-based material who are using these (and other) materials in their classroom showed increased context-based teaching competencies. The design strategy the biology innovation committee used seemed the most fruitful for acquiring context-based teaching competence when designing curriculum materials, since it incorporated some of the success factors in teacher professional development (Borko et al., 2010). This study also confirmed the study by Coenders (2010) that teachers who do not *use* context-based material after designing context-based material do not show context-based competence.

Designing curriculum materials was shown to lead to professionalisation of teachers towards context-based education. Future research could be directed at strategies for setting up design teams, such that they are in harmony with the subject to be designed for. The necessity for setting up such teams arises when the context-based curricula of the different science subjects are implemented nationwide in the Netherlands from 2013 onwards.

References

Bateman, W.L. (1990). *Open to question. The art of teaching and learning by inquiry.* San Francisco, CA: Jossey-Bass.

Bennett, J., & Lubben, F. (2006). Context-based chemistry: The Salters' approach. *International Journal of Science Education*, *28*(9), 999–1015.

Bennett, J., Lubben, F., & Hogarth, S. (2007). Bringing science to life: A synthesis of the research evidence on the effects of context-based and STS approaches to science teaching. *Science Education*, *91*(3), 347–370.

Berliner, D.C. (2001). Learning about and learning from expert teachers. *International Journal of Educational Research*, *35,* 463–482.

Boersma, K., Eijkelhof, H., Van Koten, G., Siersma, D., & Van Weert, C. (2006). De relatie tussen context en concept [The relationship between context and concept]. *Betanova*. Retrieved January 23, 2012, from http://www.betanova.nl/downloads/context/relatie_context_concept.pdf/

Boersma, K., van Graft, M., Harteveld, A. de Hullu, E., de Knecht-Van Eekelen, A., ... Van der Zande, P.A.M. (2007). *Leerlijn biologie van 4 tot 18 jaar* [A biology learning continuity pathway for K to12]. Utrecht: CVBO. Retrieved January 23, 2012, from www.nibi.nl

Borko, H., Jacobs, J., & Koellner, K. (2010). Contemporary approaches to teacher professional development. In P. Peterson, E. Baker, & B. McGaw (Eds.), *International encyclopedia of education* (3rd ed., pp. 548–556). Amsterdam: Elsevier.

Borko, H., & Putnam, R.T. (1996). Learning to teach. In D.C. Berliner & T.C. Calfee (Eds.), *Handbook of educational psychology* (pp. 673–708). London: Prentice-Hall International.

Bulte, A.M.W., Carelsen, F.J., Davids, W., Morelis, J., Jansen-Ligthelm, C., Pilot, A., et al. (2000, May). *Eenhoorn notitie* [*Eenhoorn Memorandum*] (Tech. Rep.). Retrieved from http://nieuwescheikunde.nl/Publicaties/00004/00027/

Coenders, F. (2010). *Teachers' professional growth during the development and class enactment of context-based chemistry student learning material*. Doctoral dissertation, Twente University.

Cohen, J. (1992). Quantitative methods in psychology: A power primer. *Psychological Bulletin*, *112*(1), 155–159.

Commissie Vernieuwing Natuurkunde Onderwijs HAVO/VWO [Innovation Committee High School Physics Education] (2006). *Natuurkunde leeft* [*Physics lives*]. Retrieved September 3, 2011, from www.nieuwenatuurkunde.nl

De Putter-Smits, L.G.A., Taconis, R., & Jochems, W.M.G. (2009, August 31–September 4). Developing an instrument for measuring teachers' proficiency in context-based science education: A case from the current Dutch 'coco innovation'. *Proceedings of the 2009 ESERA Conference, Istanbul, Turkey.* Retrieved January 9, 2010, from http://www.esera2009.org

De Putter-Smits, L.G.A., Taconis, R., & Jochems, W.M.G. (in press a). Mapping context-based learning environments – the construction of an instrument. *Learning Environments Research.*

De Putter-Smits, L.G.A., Taconis, R., & Jochems, W.M.G. (in press b). Chapter 8: Measuring constructivist aspects of context-based learning environments in Dutch science classrooms. In R. Taconis & P.J. Den Brok (Eds.), *Teachers creating context based learning environments in science*.

De Putter-Smits, L.G.A., Taconis, R., Jochems, W.M.G., & Van Driel, J. (2011). De emphases van docenten biologie, natuurkunde en scheikunde en de gevolgen voor curriculum vernieuwingen [Science teachers' emphases and consequences for curriculum innovations]. *Tijdschrift voor Didactiek der bèta-wetenschappen*, *28*(1), 32–48.

Deketelaere, A., & Kelchtermans, G. (1996). Collaborative curriculum development: An encounter of different professional knowledge systems. *Teachers and Teaching: Theory and Practice*, *2*(1), 71–85.

Dorman, J.P. (2003). Cross-National Validation of the What is Happening in this Class? (WIHIC) Questionnaire using confirmatory factor analysis. *Learning Environments Research*, *6,* 231–245.

Driessen, H., & Meinema, H. (2003). *Chemie tussen context en concept: ontwerpen voor vernieuwing*, [Chemistry between context and concept: Designing for innovation]. Enschede: SLO Stichting Leerplanontwikkeling Retrieved September 3, 2011 from www.nieuwescheikunde.nl

Eijkelhof, H.M.C., Holl, E., Pulepessy, B., van der Valk, A.E., Verhagen, P.A.J., & Wierstra, R.F.A. (1986). *Op weg naar venieuwing van het natuurkundeonderwijs: Een verzameling artikelen ter gelegenheid van de afronding van het project leerpakketontwikkeling natuurkunde's*. Gravenhage: SVO.

Eraut, M. (2004). Informal learning in the workplace. *Studies in Continuing Education*, *26*(2), 247–273.

Fullan, M. (1994). *The new meaning of educational change* (3rd ed.). London: Continuum Press.

George, J.M., & Lubben, F. (2002). Facilitating teachers' professional growth through their involvement in creating context-based materials in science. *International Journal of Educational Development*, *22*(6), 659–672.

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

Gräsel, C., Fussangel, K., & Parchmann, I. (2006). Professional development of teachers in learning communities: Teachers'experiences and beliefs concerning collaboration. *Zeitschrift fur erziehungswissenschaft*, *9*(4), 545–561.

Hondebrink, J.G. (1987). Vijftien jaar scheikunde (leer)plannen [15 years of chemistry (learning) pathways]. In K. Boersma (Ed.), *10 jaar leerplanontwikkeling 1975–1985* [10 years of learning pathway development 1975–1985] (pp. 47–56). Enschede: Instituut voor leerplanontwikkeling.

Hoogveld, A.W.M., Paas, F., & Jochems, W.M.G. (2005). Training higher education teachers for instructional design of competency-based education: Product-oriented versus process-oriented worked examples. *Teaching and Teacher Education: An International Journal of Research and Studies*, *21*(3), 287–297.

Johnson, B., & McClure, R. (2004). Validity and reliability of a shortened, revised version of the Constructivist Learning Environment Survey (CLES). *Learning Environments Research*, *7*(1), 65–80.

Kuiper, W., Folmer, E., Ottevanger, W., & Bruning, L. (2009a, January). *Curriculumevaluatie bètaonderwijs tweede fase: vernieuwings- en invoeringservaringen in 4 havo/vwo (2007–2008)* [Curriculum evaluation science education second phase: Experiences with the innovation and implementation in 4 havo/vwo] (Interimrapportage nieuwe scheikunde). Enschede: Stichting Leerplanontwikkeling SLO.

Kuiper, W., Folmer, E., Ottevanger, W., & Bruning, L. (2009b, January). *Curriculumevaluatie bètaonderwijs tweede fase: vernieuwings- en invoeringservaringen in 4 havo/vwo (2007–2008)* [Curriculum evaluation science education second phase: Experiences with the innovation and implementation in 4 havo/vwo] (Interimrapportage nieuwe natuurkunde). Enschede: Stichting Leerplanontwikkeling SLO.

Linn, M., Clark, D., & Slotta, J. (2003). WISE design for knowledge integration. *Science Education*, *87*(4), 517–538.

Mikelskis-Seifert, S., Bell, T., & Duit, R. (2007). Ergebnisse zur lehrprofessionalisiering im program physik im kontext. In D. Höttecke (Ed.), *Kompetenzen, kompetenzmodelle, kompetenzentwicklung* (Vol. Vol. 28, pp. 110–112). Berlin: Lit-Verlag.

Miles, M., & Huberman, A. (1994). *Qualitative data analysis: An expanded sourcebook* (2nd ed.). Thousand Oaks, CA: Sage Publications.

Nentwig, P., Christiansen, D., & Steinhoff, B. (2004). Aufgaben zur Kompetenzentwicklung – Kriterien und Beispiele der Aufgabengestaltung nach Chemie im Kontext. *Praxis der Naturwissenschaften – Chemie in der Schule*, *53*(8), 21–24.

Parchmann, I., Gräsel, C., Baer, A., Nentwig, P., Demuth, R., & Ralle the ChiK Project Group, Bernd. (2006). Chemie im Kontext': A symbiotic implementation of a context-based teaching and learning approach. *International Journal of Science Education*, *28,* 1041–1062.

Plomp, T. (1982). *Onderwijskundige technologie: enige verkenningen* [Educational technology: An exploration] (inaugural speech). Enschede, The Netherlands: University of Twente.

Roberts, D.A. (1982). Developing the concept of curriculum emphases in science education. *Science Education*, *66,* 243–260.

Ryan, G.W., & Bernard, H.R. (2000). Data management and analysis methods. In N.K. Denzin & Y.S. Lincoln (Eds.), *Handbook of qualitative research* (2nd ed., pp. 769–802). Thousand Oaks, CA: Sage Publishers.

Steering Committee Advanced Science, Mathematics and Technology (2008). *Outline of a new subject in the sciences: A vision of an interdisciplinary subject: Advanced science, mathematics and technology.* Enschede: SLO. Retrieved September 3, 2011 from www.nieuwbetavak-nlt.nl

Van Driel, J.H., Bulte, A.M., & Verloop, N. (2005). The conceptions of chemistry teachers about teaching and learning in the context of a curriculum innovation. *International Journal of Science Education*, *27*(3), 303–322.

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

Van Weert, C., & Pieters, M. (2009). Reactie nina op de stellingen van lena [Redirect of physics innovation committee on prepositions of the 'shadow' committee]. *NVOX*, *34*(4), 170–171.

Vermunt, J.D., & Verloop, N. (1999). Congruence and friction between learning and teaching. *Learning and Instruction*, *9,* 257–280.