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Assessing Teachers' Beliefs to Facilitate the Transition to a New Chemistry Curriculum: What Do the Teachers Want?

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Abstract In this article, we describe the results of a study of chemistry high school teachers' beliefs ($N = 7$) of the chemistry curriculum and their roles, their beliefs on the teacher as developer of materials, and their beliefs about professional development. Teachers' beliefs influence the implementation of a curriculum. We view the use of a new curriculum as a learning process, which should start at teachers' prior knowledge and beliefs. The results reveal that it is possible to develop a new curriculum in which teachers' beliefs are taken as a starting point. Promising approaches to prepare teachers for a new curriculum is to let them (co)develop and use curriculum materials: It creates ownership, and strengthens and develops teachers' pedagogical content knowledge (PCK).

Keywords Curriculum change and transition to a new curriculum · Teacher preparation · Teacher beliefs

Introduction

Plans to develop a new chemistry high school curriculum in the Netherlands are in an advanced stage. The question is not whether a new curriculum will be introduced, but what characteristics such a new curriculum will have. Preparing teachers for a curriculum reform is seen as a complex learning process in which teachers actively shape their own professional growth. In any learning situation, the knowledge and skills the learners already have are the starting point for the design and development of the learning processes to take place. This is also valid for teachers as learners. Curriculum developers will have to take account of teachers' knowledge, beliefs,

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and skills in developing a new curriculum; otherwise, it is unlikely that the curriculum will be implemented as intended (Cotton 2006).

The question that guided this study was to establish what chemistry teachers consider to be a good curriculum, how they envision their role as a teacher, and what their beliefs are with respect to their preparation for a new curriculum. In the following paragraphs, we will first look at the context of the study and then discuss the problems with curriculum reforms. After this, we explore what knowledge teachers draw on in their professional life and the relation between knowledge and beliefs. Finally, we turn to teacher learning.

Context of the Study

In 1999, the Dutch Ministry of Education introduced a new nationwide upper high school curriculum (for ages 16–18). The innovation was based on two main sets of requirements: (a) a new instructional design and teaching model and (b) the inclusion of more exam subjects. In the new teaching model, the teachers were no longer seen as information providers, but as facilitators of the students' learning processes. The teachers' role shifted from explaining content to coaching students. More subjects resulted in less class time per subject. Before the introduction of the new syllabus, students from the three upper high school classes had two, three, and four chemistry periods per week, respectively. After the introduction of the new curriculum, only two periods per class remained. As a consequence of the time reduction, the existing examination syllabi had to be adapted. The chemistry syllabus was mainly pruned, as a lot of topics were removed and only a few new ones added. The discontent that already existed amongst chemists about the curriculum was augmented after this operation. A discussion between stakeholders in chemistry education resulted in strategic guidelines to come to a major curricular change (Bulte et al. 2000) involving both the content and the teaching methodology. The need to redesign the curriculum was acknowledged by a committee appointed by the Dutch Ministry of Education (Van Koten et al. 2002). In a follow-up report (Driessen and Meinema 2003), recommendations for a new chemistry curriculum to be implemented in 2010 were suggested, and the crucial role the teachers play in a curriculum innovation was recognized. One of the new roles for teachers entails the development of learning materials for students. In the first stages, it is envisaged that interested teachers in small regional networks develop learning materials, validate this in their own classes, and disseminate it to other teachers. After the introduction of the new curriculum, all teachers need to be able to develop new learning materials or at least adapt existing ones.

The purpose of this study was to solicit teachers' knowledge and beliefs with respect to the current and their ideal curriculum and classroom practices as a point of departure for the development of a new curriculum and for the design and development of a teaching staff development program. The research question was: What knowledge and beliefs do chemistry teachers hold with respect to the following areas: (a) the content of the current and their ideal curriculum, (b) teacher roles, (c) the teacher as developer of curriculum materials for class use, and (d) training and support considered helpful before and during implementation.

Curriculum Reform

The introduction of large-scale science education reforms have often been problematic (Davis 2003; Fullan 1998). A number of reasons have been described in the literature for the interpretation of implementation difficulties. Many educational changes followed a model consisting of research, development, and dissemination. The research and the curriculum development were carried out by specialists; the schools and the teachers were left to implement the prescribed curriculum (Olson 2002). Innovations were often seen as organizational changes, something Fullan (1998) described as *first-order change*, ignoring the crucial role of the stakeholders, especially teachers. Another reason described by researchers for innovation problems is because dilution and interpretational changes have taken place from the ideal curriculum in the head of the developers to the attained curriculum by students (van den Akker 1988; Goodlad et al. 1979). However, the main reason found in the literature is that, although it was widely recognized that teachers are the real driving forces in any innovation, the change agencies did not act accordingly. Despite good intentions, the teachers were not or only sideways involved in the initiation, preparation, design, and development of a new curriculum (Van Veen et al. 2005). Moreover, the change agencies presented the curriculum changes as improvements without having empirical evidence for this. When the new curriculum had been drawn up by specialists, teachers were required to update their knowledge and skills (Guskey 2000) in accordance with the new curricular demands. In this perspective, change was seen as a repair program to eliminate deficits in teacher knowledge and skills. These programs consisted of "one-shot" workshops aimed at teacher mastery of prescribed knowledge and skills. Research has shown that these one-time programs failed and this brought about a shift in focus on teacher change. Change is now seen as a complex process in which teachers are active learners shaping their professional growth (Clarke and Hollingsworthe 2002; Loucks-Horsley et al. 1998). Therefore, the goal of this study is to examine the teachers' knowledge and beliefs, the teachers' learning processes, and the way these can be influenced in times of a curricular reform. Because the efficacy of a reform effort rests largely with teachers, their knowledge and beliefs need to be included in the development and implementation of a new curriculum (Ball and Cohen 1999; Keys and Bryan 2001; Lumpe et al. 2000).

Teacher Knowledge

The knowledge base for teaching has been the subject of many studies (Barnett and Hodson 2001; Cochran et al. 1993; Laplante 1997; Loughran et al. 2004; Shulman 1987; Van Driel et al. 1998; Veal 2004; Yarrick et al. 1997). A teachers' knowledge base consists of academic knowledge, pedagogical content knowledge (PCK), and experiential knowledge. Academic knowledge comprises science content knowledge, knowledge about the nature of science, and knowledge about how and why students learn. Formal university courses are the main sources for teachers to acquire this academic knowledge. PCK was initially described by Shulman (1987) as knowledge for teaching, developed from a teachers' knowledge of content and

pedagogy. Elaborating on this work, Grossman (1990) conceptualized PCK as a knowledge domain drawing on subject matter knowledge, pedagogical knowledge, and knowledge about context. The question has not been resolved whether or not PCK should be viewed as an amalgam of these knowledge domains or consists of a separate and unique knowledge domain (Gess-Newsome 1999a). However, an expert teacher has well-formed PCK for all topics taught, and this teaching knowledge is contextually bound. PCK is developed and shaped through teaching experience (Clermont et al. 1994; Van Driel et al. 1998). It is created through reflection, active processing, and integration of its contributing components. It can hardly be learned from a book or in a short course, but requires actual practice in classrooms. Experiential knowledge is defined as personal and situated knowledge about teaching and learning, acquired through experiences and, to a great extent, implicit or tacit. It is constructed in classrooms, but also during informal staff room talks and in experiences with parents. Because of its nature, experiential knowledge is highly situated.

A teachers' knowledge base is acquired and nourished through study and experience and is under constant construction and modification. It is a highly complex construct and not easily assessed (Baxter and Lederman 1999). Teachers use their knowledge base in their daily work (Barnett and Hodson 2001). In this study, attention was given to the teachers' knowledge base in relation to a curricular reform. In what content areas do teachers want to acquire new knowledge, and how do they want support to be offered?

Beliefs play a major role in the development of practical knowledge in acting like a filter through which new knowledge is interpreted and integrated (Pajares 1992; Van Driel et al. 2001). Attention for beliefs and classroom practices is necessary in both pre- and inservice teacher training as a meaningful change in one requires change in the other and vice versa (Kupari 2003).

Teacher Beliefs

Tobin and McRobbie (1996) have identified four cultural myths that guide science teachers' classroom practice: (a) The transmission mode of teaching is more effective than the use of other teaching approaches, (b) preparing students for the examinations dominates classroom practices, (c) efficiency, and (d) maintaining the rigor of the curriculum. From the innovation perspective, these myths impede change.

Numerous studies have highlighted the role of teachers' personal beliefs about content in relation to the implementation of a curriculum (Duschl and Wright 1989; Lantz and Kass 1987). Teachers did not implement curriculum materials that contradicted their ideas about content and how this content should be taught (Gess-Newsome 1999b). Materials were used if they matched the teachers' perspective, but were modified or discarded if they did not (Blake 2002; Duffee and Aikenhead 1992). Cronin-Jones (1991) described four beliefs categories influencing curriculum implementation: (a) the teacher's own role, (b) the way students learn, (c) the abilities of particular student groups, (d) and the relative importance of subject content topics. Teachers appeared to adapt a new

curriculum during implementation according to their own context and beliefs. Even when teachers initially subscribe to a reform developed by others, there is no guarantee that the reform is implemented or sustained. Rousseau (2004) reported about a teacher community who began and later abandoned a reform. These teachers' beliefs about teaching and learning conflicted with their beliefs about their students. Teachers argued that their students' struggle to cope with the new curriculum demands required them to revert to old teaching habits. A similar course of events is reported in a case study by Van Veen et al. (2005), where an initially reform-enthusiast teacher, because of personal, moral, and social concerns, developed negative emotions toward the most important aspect of the particular reform.

Evers et al. (2002) found that teachers in the Netherlands with strong self-efficacy beliefs seem to be more prepared to experiment with, and later to implement, new educational practices. This view is supported by the finding that the way teachers react to a reform is largely determined by whether or not "the teachers perceive their professional identities as being reinforced or threatened by reforms" (Van Veen and Sleegers 2006, p. 106).

In times of educational reforms aimed at changing teaching practices for the better, the intertwined nature of teachers' knowledge and beliefs and their emotions and cognitions are revealed more prominently. Reform policies that affect their classrooms, give rise to more intense teacher emotions toward the reform (Schmidt and Datnow 2005). Imposing different normative beliefs on teachers in reforms may elicit actions of resistance (Kelchtermans 2005). Because of their importance, the main goal of this study was to solicit teachers' beliefs in relation to a curricular reform.

Teacher Learning and Reform of Practice

Loucks-Horsley et al. (1998) argued that teachers need to experience for themselves the science learning in which they want to engage their students. The professional development program used by Jeanpierre, Oberhauser, and Freeman (2005) was based on this premise, and they found that it is possible to change a large part—though not all—of these teachers' educational practices. The success of the program was attributed to the presentation of deep science content and process knowledge, with numerous opportunities for practice.

In another study, teachers reverted to previously mastered teaching techniques and even retained subject content from previously taught classes (Lantz and Kass 1987) when new teaching approaches were not accompanied by the mastery of knowledge and new patterns of practice (Hollon et al. 1991). The authors suggested that merging of aspects of a new curriculum with topics and practices teachers valued most from previous teaching experiences was required.

A number of studies report about the use of curriculum materials to support teacher learning. A group of researchers developed teacher guides containing how-to-do advice for teachers in potentially vulnerable areas, such as lesson preparation, lesson content, teaching role, and evaluation (van den Akker 1988; Roes,

Unpublished doctoral dissertation 1997; Voogt, Unpublished doctoral dissertation 1993). The use of these materials with procedural specifications resulted in fewer implementation problems. Ball and Cohen (1996) proposed that curriculum materials for students should also be designed as educative for teachers, providing explicit support for learning about teaching. According to Schneider et al. (2005), the use of materials with detailed lesson descriptions and specific, consistent support for teacher thinking can help with enactment, though this is not sufficient. In the authors' views, reform attempts must include professional development and an effort to create systemic change in context and policy. One of the difficulties in the development of educative materials is the dilemma in the quantity of direction: give too much direction and teachers may loose any sense of ownership, give too little and teachers do not know what to do (Pintó 2005).

As teachers' knowledge, experiences, and beliefs greatly impact classroom practices, teacher learning must be a key ingredient in educative reform (Pintó 2005). Just as for students, learning activities for teachers must take their knowledge, beliefs, and skills into account (Davis 2003; Lieberman 1995). Professional development programs should attend to the diverse behaviors and beliefs of its participants (Cotton 2006; Luft 2001). The teachers' professional growth is supposed to be a complex process, having an idiosyncratic nature (Clarke and Hollingsworthe 2002). It is not only important to find out what teachers think of a reform, but also to identify what they perceive to be their task and why (Olson 2002).

The question that guided this study was whether or not it is possible to develop a new chemistry curriculum that takes the knowledge and beliefs of the teachers as a starting point, after these have been assessed. Researchers (Cronin-Jones 1991; de Vries, Unpublished doctoral dissertation 2004) have shown that beliefs teachers have with respect to curriculum content and teacher roles are important during curriculum reforms. These two aspects were, therefore, included in this study. As teachers are often codevelopers of learning materials for students, it was also of interest to assess their beliefs in this area. In any reform, teachers will need to be trained and supported (Schneider et al. 2005); and we, therefore, also solicited the teachers' beliefs on professional development programs and activities.

Method

Participants

Seven[1] high school teachers employed at different schools throughout the Netherlands (three female and four male and all having a chemistry Master's degrees and a teaching qualification) were selected and interviewed. For the

[1] Two teachers from different schools wanted to be interviewed together because they had cooperated closely as a team during the development of innovative classroom materials. This interview, in which the same issues were addressed as in the other interviews, resulted in one transcript. It is presented under teacher G.

selection of the teachers, four criteria were used: (a) Teachers should be familiar with the discussion on the new chemistry curriculum and with the main recommendations in the Van Koten et al. (2002) reported to be able to relate to these recent developments; (b) As we wanted the teachers to comment on the curriculum content, they needed an open mind to new developments in chemistry and teaching; (c) we wanted the teachers to assess the situation in chemistry classes and they should, therefore, be willing to reflect on their classroom practices; and (d) Teachers should have recent and up-to-date teaching experience. Of the selected teachers, six were very experienced, each having more than 20 years. Only one teacher was less experienced, having 2 years. One teacher is a co-author of a chemistry high school book; one teacher was involved in the development of materials for practical work; one teacher was involved in the construction of evaluation questions; one has experience with the construction of curriculum materials, and one teacher is involved in the development and use of prototype materials for chemistry in context. Only one of the experienced teachers and the less experienced teacher had no specific field of expertise outside the teaching profession. All teachers were active teachers at the time they were interviewed, each having recent and up-to-date classroom experiences.

Instruments

In order to permit teachers to express their own ideas without guiding their responses and because of the complexity of teachers' personalities and their belief structures, we decided to interview the teachers instead of using a questionnaire. The interviews took between 60 and 90 min and were conducted in a period of 6 weeks. A semistructured interview guide organized the interviews. Four areas were addressed:

1. Teachers' beliefs about the curriculum content: (a) What essential elements do you think should be present in assignments, exercises, and other student activities to facilitate students' knowledge construction? and (b) What do you consider an ideal chemistry curriculum in terms of representative chemistry content?
2. Teachers' beliefs about their roles: (a) What roles in relation to your students do you have as a chemistry teacher? And (b) What roles do you have with respect to self-regulated learning?
3. Teachers' beliefs about the development of learning materials: (a) What kind of learning materials did you, yourself, develop so far? And (b) What are your beliefs on teachers as developers of learning materials?
4. Teachers learning and reform of practice: (a) Do you think you want support for (i) chemistry content and chemistry didactical content? (ii) the use of cooperative learning assignments? (iii) evaluation of learning results? or (iv) the use of information and communication technology (ICT) applications? and (b) How would you like to receive this support? (i) as a course? (ii) as exemplary material that contains procedural specifications? (iii) in the form of developing educational materials with others? or (iv) as teacher guides?

Data and Data Processing

Data processing and analysis consisted of four phases. First, all interviews were transcribed verbatim. To establish common beliefs in the seven transcripts, a three-step protocol analysis procedure was used (Coenders 2003).

In the first step, each transcript was examined to determine sentences or phrases considered characteristic for the given response. These characteristic phrases were highlighted in the transcripts and subsequently tabulated in a created word table. This resulted in seven word tables containing the characteristic phrases per interview.

In the second step of the procedure, the characteristic phrases from all the interviewees per question were organized in a new word table. This resulted in a word table for each question. Each table was comprised of all the characteristic phases from all interviewees on that question.

In the third step, common elements were determined in each word table from step two to enable generalizations. These common elements were transferred to a new word table in which a plus (+) sign was used to indicate that an interviewee had mentioned that element. Tables obtained after this step are shown in the results section.

Determination of the Reliability

To determine the reliability of the data processing two tests were carried out (a test of the reliability of the results and the interrater reliability). Four chemistry teachers not involved in the research were requested to act as assessors and check the processed data against the interview transcripts. To limit their time investment, a representative sample check was carried out.

To determine the reliability of the results, the assessors were given the data table that was obtained after step three of the data processing, plus the corresponding interview transcripts. They were asked to indicate, comparing the table with the transcript, whether or not they could support or would reject the statement made in the table, and secondly, to determine if statements were missing in the table. A random sample was selected per assessor consisted of three processed tables and for each table the transcripts of two interviews. Of the items the assessors judged in this way, 91% were in full agreement, 3% were partly supported, and the other 6% were not agreed upon.

To establish the interrater reliability, all four assessors were asked to judge the processed data of one specific table against the transcripts of the same three interviews. This resulted in 94% full agreement.

Results

Teachers' Beliefs About the Curriculum Content: Essential Elements in Assignments to Foster Knowledge Construction

As can be see in Table 1, all teachers wanted a gradual shift from simple to more complex assignments. As one teacher said: "The cognitive aspect is first a matter of

Table 1 Essential elements in assignments and exercises to facilitate knowledge construction

Assignments and exercises need to	Teacher							
	A	B	C	D	E	F	G	%
Start simple and gradually become more complex	+	+	+	+	+	+	+	100
Support construction of a knowledge network			+		+		+	43

Note: The plus (+) sign is used to indicate teachers who mentioned the particular element. A letter is used to indicate the interviewed teacher

checking understanding of the content and, if one can reproduce, it that is sufficient. Then it should be applied or recognized in other situations."

Implicitly, teachers also provided information on the content of the assignments. First of all, assignments need to contain elements that encourage students to look for relevant information in their textbook or some other information source to reproduce this knowledge. After this, the students need to be stimulated to apply the knowledge, first in a more or less familiar context. One of the teachers phrased it as follows: "Training exercises will always be necessary ... The next phase would require students to apply what they learned to a context, for example, a product label."

Three teachers explicitly mentioned the transition from closed to more open assignments. The goal of the open assignments is the integration of knowledge domains and skills acquisition, not so much practicing specific content. As one teacher phrased it: "I find open assignments crucial, but the question is whether or not these do support knowledge construction or mainly the acquisition of skills?"

According to three teachers, assignments need to support the construction of knowledge networks. Two of these teachers indicated that reflection on the learning results will also contribute to the creation of knowledge networks and to the development of metacognitive skills. One of the teachers mentioned how students can construct their knowledge network: "Assignments in which they do not have to apply the theory directly, but for which they need to show a helicopter view on the theory … like the construction of a concept map."

Curriculum Content: Ideal Chemistry Curriculum

Basic concepts, like chemical bonding, concentration, and organic chemistry, were mentioned by five of the respondents as typical components of an ideal curriculum (see Table 2). These teachers also indicated that some topics should be removed from the current curriculum: mass spectroscopy, redox reactions, entropy. Existing overlap between subjects (e.g., with biology in biochemistry) has to be reduced.

There was support from five of the interviewees for the prominent place that positive developments in chemistry should have in a new curriculum. Negative aspects of chemistry application, like pollution and environmental damages, often appear in the news headlines. The important contribution of chemistry to our modern society needs a more prominent place in a new curriculum. Modern chemistry applications are indicative because six of the teachers especially wanted

Table 2 Perceived characteristics of an ideal chemistry curriculum

Typical characteristics of an ideal chemistry curriculum	Teacher							
	A	B	C	D	E	F	G	%
Basic concepts (bonding, concentration, particles); organic chemistry	+	+		+		+	+	71
Positive developments in chemistry in a more prominent role	+		+	+	+		+	71
Modern applications of the discipline		+	+	+	+	+	+	86
Practicals, skills, research	+	+			+	+	+	71
Aspects students will be confronted with (later): knowledge must influence behavior			+	+	+			43

to incorporate state of the art chemistry developments in a new curriculum. One of these teachers formulated this as follows: "The positive developments in chemistry need to get a more central role—and, then, also the current developments."

Five of the teachers mentioned the students' practical activities as a characteristic of a chemistry curriculum. Three teachers stated that what students learn needs to influence their behavior.

Current Curriculum: General Remarks Made by the Interviewees

All teachers talked about the main difficulties in the current curriculum, although the interviewer did not bring this issue up. Lack of time was a complaint that emerged over and over. Insufficient class time made it difficult to establish common ground with students: "You hardly see them [the students] because there is so little class time."

The school curriculum as a whole was considered to be overloaded. Teachers said that their students struggled with deadlines all the time as the number of assignments, for all subjects, was high: "Because of the overburdening of the students as a result of all these practical assignments."

Time was wasted because of insufficient coherence, both between the topics and between related subjects. Teachers expressed the feeling that during the development of this curriculum, the innovation, self-regulated learning of students, was not taken as a starting point, but the existing chemistry curriculum had only been pruned and polished. The teachers attributed most problems the students encountered to requirements from outside the chemistry curriculum, not to difficult topics in the curriculum itself.

Teachers' Beliefs About Their Roles

The role of instructor, in the sense of explaining content, was mentioned by five teachers (Table 3). Phrasing and answering questions was brought up by four of the respondents. These two roles are directly related to the subject matter content.

Making students enthusiastic was mentioned by four teachers and maintaining a pleasant working atmosphere was mentioned by two. Three teachers talked about

Table 3 Perceived roles as chemistry teacher

Perceived teacher roles	Teacher							
	A	B	C	D	E	F	G	%
Explain content; instructor	+	+			+	+	+	71
Phrase or answer questions	+		+		+		+	57
Make students enthusiastic		+	+			+	+	57
Maintain a pleasant working atmosphere		+		+				29
Manage the learning process	+		+			+		43
Guide–coach				+	+	+	+	57

Table 4 Perceived teacher roles with respect to self-regulated learning

Role with respect to self-regulated learning	Teacher							
	A	B	C	D	E	F	G	%
No explicit role in chemistry education	+	+						29
Teach how-to-learn				+	+		+	43
Teach how-to-plan			+		+		+	43

the role of managing the students' learning processes; four did not mention this role explicitly.

Four teachers believed to have a guiding or coaching role. One of these teachers decidedly mentioned the upbringing task as the most important school objective, especially for this age group. In his opinion, these students have to be guided through adolescence, a difficult period in their lives: "Your students grow older, and you play a role in this." This teacher also considered relating chemistry to students' life world to be more important than teaching subject content per se: "Something should start living in students; they should be able to relate it to something familiar."

Only three teachers mentioned teach how to learn and teach how to plan as clear tasks within chemistry education (Table 4). However, it is unclear how this should be carried out in practice. As one teacher said:

> So the students you think would require a lot of your coaching role do not make use of this.…My task is to see to it that students do have questions. I don't know yet how to do this. That is learning and the uncertainty I now have myself.

Teachers' Beliefs About the Development of Learning Materials

The responses to the questions are summarized in Table 5. Teachers were encouraged to mention whatever they perceived as development tasks. In the second question, a broad description for development task was adopted—from

Table 5 Development work carried out and beliefs about the teacher as developer

Developed learning materials	Teacher							
	A	B	C	D	E	F	G	%
Open assignments	+	+			+		+	57
Just adapting materials	+		+		+	+		57
Complete chapters					+		+	29
Beliefs about teacher as developer								
Combination developer-teacher is motivating		+	+		+	+	+	71
Professionals have to do the developing				+			+	29

making worksheets with exercises to describing student practicals and writing of complete topic chapters. All teachers expressed that a full teaching load in the current school practice leaves insufficient time for the development of learning materials.

Experience with the development of materials was diverse, as can be seen in Table 5. Four teachers have developed open assignments and made adaptations in existing materials. Only two teachers have written complete topic chapters.

With respect to beliefs about the teacher as developer, five teachers reported that finding development tasks in combination with teaching in motivating, under the condition that sufficient time is available. One of these teachers phrased this as follows: "... maybe about 10–15%. I like developing new things, but it should not become my main task."

Two teachers expressed that the development of learning and teaching materials should be left to professionals; these professionals could, however, be teachers who can spend "minimal 1 day per week for development tasks" as part of their teaching profession, which would certainly require a major reduction in teaching load.

Teachers' Learning and Reform of Practice

As can be seen in Table 6, most teachers wanted support in the four areas mentioned by the interviewer, the duration and extent depending on the depths and breaths of the innovation. Three teachers said that they considered assistance in ICT applications only useful when the support offered had a direct bearing on their

Table 6 Perceived areas of support in preparation of a new curriculum

Support areas to prepare for a new curriculum	Teacher							
	A	B	C	D	E	F	G	%
Content (plus didactical)	+	+	+	+	−	+	+	86
Cooperative learning assignments	+	+	−	+	+	+		71
Evaluation of learning results	+	+	+	+	+	+		86
ICT	+	±	±	−	+	±		71

Table 7 Perceived ways of support in preparation of a new curriculum

Ways of support in preparation of a new curriculum	Teacher							
	A	B	C	D	E	F	G	%
Course	±	+	+	+	+	+	+	100
Exemplary material	+	+			+			43
Develop (with others) educational material	+	+	+	+	+	+	+	100
Teacher guides	+	+			+	+		57

teaching and when the course was offered at school. These teachers also acknowledged that students are more computer literate than they, themselves, are and that the difference is widening.

In Table 7, the kind of support teachers would like to receive is reported. Of the four alternatives offered, a course was preferred when specific knowledge and skills need to be acquired, especially when the course could be held at school. The advantage of the latter would be that all materials and computer programs are in place and in working condition and can be used, even after the course. One teacher reported to be happy with a course offered at school: "We had a course in school with about twenty colleagues under supervision from someone from a college and I consider this a good way of inservice training."

Merely written resources were less appreciated. Exemplary material that contained specifications for class use was new to most teachers. They had never used it, and characteristics had to be explained to them before they could answer the questions. Three of the respondents considered exemplary materials helpful. The use of teacher guides was appreciated by four of the teachers. All teachers believed that involvement in the development of learning materials to be a strong opportunity to get ready for a new curriculum.

Discussion

Teacher Knowledge

Teachers appear to be self-knowledgeable. They spoke frankly about their qualities and their strong and weak sides and were able to indicate in what areas they need to acquire knowledge and skills. Teachers use the syllabus requirements to determine whether or not their knowledge and skills are sufficient, and they compare their own school practice with practices of colleagues.

Surprisingly, teachers felt uneasy when asked about their role in stimulating self-regulated learning. They do not know how to realize this in their own practice. As self-regulated learning was one of the pillars of the 1999 curriculum renewal, this aspect of that reform could be assessed as being not very successful.

Although the proposed context-concept approach by Driessen and Meinema (2003) can count on cautious approval, teachers felt uneasy about the implications for the students' learning processes. They wondered whether or not their knowledge

would be adequate to support students when they engaged in a learning process based on a context–concept approach. The academic and PCK domains need to be updated.

Teacher Beliefs

The teachers recognized that the current curriculum is outdated, and they shared the belief that a curriculum overhaul is necessary. The data show that teachers hold strong beliefs about the conditions a chemistry curriculum should meet in terms of assignments and exercises. The student activities must start simple and gradually become more complex. Teachers first want to assess students' knowledge and understanding of basic principles before moving on to more complex learning situations as applications and open assignments. Scaffolding activities to construct a knowledge network and activities to foster reflection on the learning process and learning results should be incorporated in students' learning activities.

The results further show that all the teachers have firm beliefs about the content of a chemistry curriculum. Positive developments in chemistry and state-of-the-art applications, the covering of basic concepts, and the use of experiments all require a prominent place. It is not so much the specific topics featured in the curriculum that teachers are worried about, but more the class time available to cover the content and the rationality within the science curriculum as a whole. One of the ways to achieve more coherence is to reduce the overlap with the related subjects of biology and physics. Because of the nature of chemistry, the students' practical work requires a prominent place in the curriculum. Practical work is believed to be not merely important because of the acquisition of practical and investigative skills, but also to instigate the integration of knowledge domains. As practical work is time consuming, sufficient class time is a prerequisite. There are two possible ways to realize adequate class time. A reduction of the number of subjects in a new curriculum will create more study time per subject. Or, if the first option is politically unacceptable, a reduction of the examination syllabus for chemistry will also create time for students to do experiments. This second option can also count on teacher approval.

Based on these conditions, it seems possible to develop a new chemistry curriculum that is acceptable to all the teachers. It should be flexible in nature to leave room for teachers to make choices according to their own preferences.

How teachers perceive their roles has a direct bearing on what happens inside the classroom (Schmidt and Datnow 2005). Changing classroom practices, therefore, requires at least a reflection on possible roles. The data on the teacher roles show that all the interviewed teachers belief they have different roles. Each teacher mentioned two or more roles; they all believed that teaching is a multifaceted profession in which teachers have to take up different responsibilities and tasks. Teachers' beliefs on their roles pertained to the three domains from the teachers' knowledge base. From the academic knowledge domain, intertwined with the PCK domain, teachers mentioned: explaining content and instructing students, phrasing and answering questions, and making students enthusiastic for the discipline. That these three roles were often mentioned is not surprising as these teachers were

educated for these roles during their teacher preparation programs; and, being very experienced, they have used these in their classes for a long time. A typical role from the experiential knowledge domain, maintaining a pleasant working atmosphere, is only mentioned twice. Almost all of the teachers believed it was important to play a role in managing the learning process and guiding or coaching students. Both of these roles are partly new for these teachers as they only received explicit attention in the new curriculum introduced in 1999. One teacher holds very outspoken beliefs about the upbringing of the students. Raising children in this belief is by far the most important task for a teacher and a school: Students, first of all, need to be guided to become responsible citizens.

Because learning materials have to be used in classrooms, it is necessary to take teachers' beliefs regarding these materials into account (Cotton 2006; Rousseau 2004). One way of achieving this is to involve teachers in the development of these materials (Kupari 2003). All interviewed teachers developed their own performance tests, and all considered this a normal teacher task, also for the future. The skills teachers have acquired in this area can be broadened to develop learning materials and learning activities.

Although nearly all teachers have developed some kind of learning materials for class use, a large variety exists in the depth and breadth of these developed materials. Some teachers have adapted existing materials to their specific situation. Others have developed comprehensive, innovative materials comprising texts, assignments, and practical activities for students, including teacher guides for teachers and teaching assistants.

The teachers who, in addition to their part-time teaching load, were engaged in the development of more comprehensive learning materials, perceived it to be very rewarding and looked forward to continuing this in future. The combination of teaching and writing curriculum materials is considered especially valuable. A writer needs to know what fascinates students and how they learn and think. A teacher has direct contact with students and experiences how they acquire knowledge and skills. Teacher-writers combine these two sides and are in the position of testing materials in a very early development stage with their students.

In a school setting in which teachers have a full teaching load, insufficient time for development activities is available. Teachers indicated to be interested in having more of these tasks as part of their normal working load, at the same time acknowledging the requirement of professionalism.

Teacher Learning and Reform of Practice

Teachers hold strong beliefs about the usefulness of different kinds of assistance. For ICT, a course at school is believed to be the most valuable. Teachers not only learn how to use the materials, but all materials, including hard- and software, will be locally available during and after completion of the course. Offering inservice courses at school for a whole team of teachers will contribute to the growth of the teacher self-efficacy (Evers et al. 2002; Friedman and Kass 2002) and foster cooperation between the teachers (Davis 2003). Explicit attention to the situation in the school can be given, making the course gain in practicality.

When it comes to chemistry content and knowledge typically from the academic knowledge domain, the interviewed teachers preferred a course. This reflects how teachers acquired this kind of knowledge in the past.

Toward a New Curriculum

People's beliefs are powerful motivation agents. If teachers believe something to be true, they are likely to act accordingly. To attend to both beliefs and practices is essential as a change in one requires a change in the other (Kupari 2003). Teachers' understanding of the curriculum materials, their beliefs about what is important, and their beliefs about the roles of the students and the teachers all strongly shape their practice (Ball and Cohen 1996). The uncertainty teachers experience in times of curriculum change (Van Veen and Sleegers 2006) clearly emerged from these interviews. The concerns teachers expressed are related to their own practices and experiences. Teachers wonder how they can play a supportive role in ICT as they observe that their students' computer skills are far better developed than their own.

Fullan (1998) described change as a learning process and as a journey. An effective learning process presupposes that teachers' prior knowledge and beliefs be taken as the starting points. Change agents need to be aware of what teachers already know, can do, and believe.

Teachers need to become more aware of and reflect on their beliefs and understandings about learning, teaching, students, and the subject matter (Davis 2003; Pintó 2005). Confidence needs to be built, as teachers have to take risks in enacting a new way of teaching (Ball and Cohen 1999; Guskey 2000). Consensus exists between the interviewed teachers about the subject content of a new curriculum. The recommendations and the directions, as indicated by Van Koten et al. (2002) and Driessen and Meinema (2003), found approval. Also, with respect to support before and during a curriculum change, general accordance exists.

A possible learning process in which teachers' prior knowledge and beliefs are taken seriously can, therefore, have the following characteristics. The starting point is the idea to let teachers develop curriculum materials for class use. This requires reflection on his or her own practice, creates at the same time ownership (Fullan 1998; Pintó 2005), boosts teacher self-efficacy, and teachers develop new PCK during class use. In this scenario, teachers are (co)producers of innovative practices (Evers et al. 2002). Conditions for teacher as developer are the allocation of sufficient time for the development tasks, support for teachers to clarify and learn new teacher roles, and support in specific content areas. If the curriculum reform requires the acquisition of academic knowledge, the organization of a course at the school of the participating teachers will be effective. Teacher personal growth can now really be an amalgam of practice, meaning, and context (Clarke and Hollingsworthe 2002).

Implications for Further Research

One of the limiting factors in this research is that the number of interviewed teachers is relatively small. This, in combination with the strategy to let teachers speak out freely with a limited number of guiding questions, hampers generalizations. We

intend to use the results of this work to follow a few teachers involved in the development of classroom materials more closely during a longer period.

The scenario of teachers as developers of (part of) their curriculum materials looks promising, though the issues of quality control, acceptance of the materials by colleagues, and clarification of what the developers learn in this process all need further research.

References

Ball, D. L., & Cohen, D. K. (1996). Reform by the book: What is—or might be—the role of curriculum materials in teacher learning and instructional reform? *Educational Researcher*, *25*, 6–14.

Ball, D. L., & Cohen, D. K. (1999). Developing practice, developing practitioners. In L. Darling-Hammond, & G. Sykes (Eds.), *Teaching as the learning profession. Handbook of policy and practice* (pp. 3–32). San Francisco: Jossey-Bass.

Barnett, J., & Hodson, D. (2001). Pedagogical context knowledge: Toward a fuller understanding of what good science teachers know. *Science Education*, *84*, 426–453.

Baxter, J. A., & Lederman, N. G. (1999). Assessment and measurement of pedagogical content knowledge. In J. Gess-Newsome, & N. G. Lederman (Eds.), *Examining pedagogical content knowledge* (pp. 147–161). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Blake, R. W. (2002). *An enactment of science: A dynamic balance among curriculum, context, and teacher beliefs*. New York: Peter Lang.

Bulte, A. M. W., Carelsen, F. J., Davids, W., Morelis, J., Jansen-Ligthelm, C. D., Pilot, A., Velthorst, N. H., & de Vos, W. (2000). *Nieuwe Scheikunde. Hoofdlijnennotitie over een voorstel tot fundamentele herziening van het scheikundeprogramma voor de bovenbouw van havo en vwo* [New chemistry. A proposal for fundamental review of the chemistry high school curriculum]. Enschede, The Netherlands: SLO.

Clarke, D., & Hollingsworthe, H. (2002). Elaborating a model of teacher professional growth. *Teaching and Teacher Education*, *18*, 947–967.

Clermont, C. P., Borko, H., & Krajcik, J. S. (1994). Comparative study of the pedagogical content knowledge of experienced and novice chemical demonstrators. *Journal of Research in Science Teaching*, *31*, 419–441.

Cochran, K. F., DeRuiter, J. A., & King, R. A. (1993). Pedagogical content knowing: An integrative model for teacher preparation. *Journal of Teacher Education*, *44*, 263–272.

Coenders, F. G. M. (2003). *Kennis en opvattingen van scheikundedocenten* [Chemistry teachers' knowledge and beliefs]. Enschede, The Netherlands: Universiteit Twente, ELAN.

Cotton, D. R. E. (2006). Implementing curriculum guidance on environmental education: The importance of teachers' beliefs. *Journal of Curriculum Studies*, *38*, 67–83.

Cronin-Jones, L. L. (1991). Science teacher beliefs and their influence on curriculum implementation: Two case studies. *Journal of Research in Science Teaching*, *28*, 235–250.

Davis, K. S. (2003). "Change is hard": What science teachers are telling us about reform and teacher learning of innovative practices. *Science Education*, *87*, 3–20.

Driessen, H. P. W., & Meinema, H. A. (2003). *Chemie tussen Context en concept* [Chemistry between context and concept]. Enschede, The Netherlands: SLO.

Duffee, L., & Aikenhead, G. (1992). Curriculum change, student evaluation, and teacher practical knowledge. *Science Education*, *76*, 493–506.

Duschl, R. A., & Wright, E. (1989). A case study of high school teachers' decision making models for planning and teaching science. *Journal of Research in Science Teaching*, *26*, 467–501.

Evers, W. J. G., Brouwers, A., & Tomic, E. (2002). Burnout and self-efficacy: A study on teachers' beliefs when implementing an innovative educational system in the Netherlands. *British Journal of Educational Psychology*, *72*, 227–243.

Friedman, I. A., & Kass, E. (2002). Teacher self-efficacy: A classroom-organization conceptualization. *Teaching and Teacher Education*, *18*, 675–686.

Fullan, M. G. (1998). *The new meaning of educational change*. London: Cassell.

Gess-Newsome, J. (1999a). Pedagogical content knowledge: An introduction and orientation. In J. Gess-Newsome, & N. G. Lederman (Eds.), *Examining pedagogical content knowledge* (pp. 3–17). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Gess-Newsome, J. (1999b). Secondary teachers' knowledge and beliefs about subject matter and their impact on instruction. In J. Gess-Newsome, & N. G. Lederman (Eds.), *Examining pedagogical content knowledge* (pp. 51–94). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Goodlad, J. I., Klein, M. F., & Tye, K. A. (1979). The domains of curriculum and their study. In J. I. Goodlad (Ed.), *Curriculum inquiry: The study of curriculum practice* (pp. 43–76). New York: McGraw-Hill.

Grossman, P. (1990). *The making of a teacher: Teacher knowledge and teacher education*. New York: Teachers College Press.

Guskey, T. R. (2000). *Evaluating professional development*. Thousand Oaks, CA: Corwin Press.

Hollon, R. E., Roth, K. J., & Anderson, C. W. (1991). Science teachers' conceptions of teaching and learning. In J. Brophy (Ed.), *Advances in research on teaching* (Vol. 2, pp. 145–186). Greenwich, CT: JAI.

Jeanpierre, B., Oberhauser, K., & Freeman, C. (2005). Characteristics of professional development that effect change in secondary science teachers' classroom practices. *Journal of Research in Science Teaching*, *42*, 668–690.

Kelchtermans, G. (2005). Teachers' emotions in educational reforms: Self-understanding, vulnerable commitment, and micropolitical literacy. *Teaching and Teacher Education*, *21*, 995–1006.

Keys, C. W., & Bryan, L. A. (2001). Coconstructing inquiry-based science with teachers: Essential research for lasting reform. *Journal of Research in Science Teaching*, *38*, 631–645.

Kupari, P. (2003). Instructional practices and teachers' beliefs in Finnish mathematics education. *Studies in Educational Evaluation*, *29*, 243–257.

Lantz, O., & Kass, H. (1987). Chemistry teachers' functional paradigms. *Science Education*, *71*, 117–134.

Laplante, B. (1997). Teachers' beliefs and instructional strategies in science: Pushing analysis further. *Science Education*, *81*, 277–294.

Lieberman, A. (1995). Practices that support teacher development. *Phi Delta Kappan*, *76*, 591–596.

Loucks-Horsley, S., Hewson, P. W., Love, N., & Stiles, K. E. (1998). *Designing professional development for teachers of science and mathematics*. Thousand Oaks, CA: Corwin Press.

Loughran, J., Mulhall, P., & Berry, A. (2004). In search of pedagogical content knowledge in science: Developing ways of articulating and documenting professional practice. *Journal of Research in Science Teaching*, *41*, 370–391.

Luft, J. A. (2001). Changing inquiry practices and beliefs: The impact of an inquiry-based professional development programme on beginning and experienced secondary science teachers. *International Journal of Science Education*, *23*, 517–534.

Lumpe, A. T., Haney, J. J., & Czerniak, C. M. (2000). Assessing teachers' beliefs about their science-teaching context. *Journal of Research in Science Teaching*, *37*, 275–292.

Olson, J. (2002). Systematic change/teacher tradition: Legends of reform continue. *Journal of Curriculum Studies*, *34*, 129–137.

Pajares, M. F. (1992). Teacher beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research*, *62*, 307–332.

Pintó, R. (2005). Introducing curriculum innovations in science: Identifying teachers' transformations and the design of related teacher education. *Science Education*, *89*, 1–12.

Rousseau, C. K. (2004). Shared beliefs, conflict, and a retreat from reform: The story of a professional community of high school mathematics teachers. *Teaching and Teacher Education*, *20*, 783–796.

Schmidt, M., & Datnow, A. (2005). Teachers' sense-making about comprehensive school reform: The influence of emotions. *Teaching and Teacher Education*, *21*, 949–965.

Schneider, R. M., Krajcik, J., & Blumenfeld, P. (2005). Enacting reform-based science materials: The range of teacher enactments in reform classrooms. *Journal of Research in Science Teaching*, *42*, 282–312.

Shulman, S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, *57*, 1–22.

Tobin, K., & McRobbie, C. J. (1996). Cultural myths as constraints to the enacted science curriculum. *Science Education*, *80*, 223–241.

van den Akker, J. J. H. (1988). *Ontwerp en implementatie van natuuronderwijs* [Design and implementation of science education]. Lisse, The Netherlands: Swets & Zeitlinger.

Van Driel, J. H., Bijaard, D., & Verloop, N. (2001). Professional development and reform in science education: The role of teachers' practical knowledge. *Journal of Research in Science Teaching*, *38*, 137–158.

Van Driel, J. H., Verloop, N., & de Vos, W. (1998). Developing science teachers' pedagogical content knowledge. *Journal of Research in Science Teaching*, *35*, 673–695.

Van Koten, G., de Kruijff, B., Driessen, H. P. W., Kerkstra, A., & Meinema, H. A. (2002). *Bouwen aan scheikunde. Blauwdruk voor een aanzet tot vernieuwing van het vak scheikunde in de Tweede Fase van het HAVO en VWO* [Building on chemistry. A blueprint to come to a new chemistry high school curriculum]. Enschede, The Netherlands: SLO.

Van Veen, K., & Sleegers, P. (2006). How does it feel? Teachers' emotions in a context of change. *Journal of Curriculum Studies*, *38*, 85–111.

Van Veen, K., Sleegers, P., & van de Ven, P. H. (2005). One teacher's identity, emotions, and commitment to change: A case study into the cognitive-affective processes of a secondary school teacher in the context of reforms. *Teaching and Teacher Education*, *21*, 917–934.

Veal, W. R. (2004). Beliefs and knowledge in chemistry teacher development. *International Journal of Science Education*, *26*, 329–351.

Yarrick, R., Park, H., & Nugent, J. (1997). Struggling to promote deeply rooted change: "The filtering effect" of teachers' beliefs on understanding transformational views of teaching science. *Science Education*, *81*, 137–159.