Attending to the knowledge, skills, and attitudes of teachers and students: Guidelines for context-based chemistry curricula

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Summary

Chemistry education is often considered challenging by students, because concepts are often isolated. Context-based education (CBE) has shown to improve students' motivation, because it uses an authentic context as the starting point from which chemistry concepts emerge. Throughout history, many attempts at curriculum reform have failed, because they adopt a top-down approach that fails to pay close attention to the curriculum enactment. CBE can be a challenge for teachers and students, because it requires significant changes in their behaviour. The present study examines the self-perceived knowledge, skills and attitudes of teachers and students towards the proposed pedagogical framework. The study is carried out within the context of the Impuls project, a 2-year project initiated by the University of Twente. Within this project, a teacher design team (TDT) is co-designing context-based chemistry materials for secondary schools, where the learning activities are organized according to the 5E instructional model (Engage, Explore, Explain, Elaborate, and Evaluate). The findings are used to develop specific guidelines for designing curriculum materials with the CBE – 5E pedagogy that can be used by designers to create materials that promote curriculum reform. The main research addressed in this study is: *How can curriculum materials help foster the knowledge, skills and attitudes of teachers and students towards teaching and learning with the 5E model in a context-based chemistry curriculum inspired by authentic chemistry challenges?* Qualitative data was collected through a focus group with expert teachers and group interviews with teachers and students to explore their knowledge, skills and attitudes. Quantitative data was collected with a questionnaire to examine if the initial findings could be substantiated by a lager sample. The results showed that teachers have considerable knowledge of the CBE – 5E pedagogy and are confident of their context-based skills and recognize the value of the approach. The teachers do express to struggle with the unorthodox teaching methods. Furthermore, they express several concerns regarding the success and feasibility of CBE, such as determining when just-in-time information is needed, lack of structure and classroom management. The students have less knowledge of the proposed pedagogical framework. They are relatively confident of their context-based skills, but stress the importance of sufficient structure and guidance. Although the interviewed students believe that CBE increases their motivation and enjoyment of chemistry, the questionnaire does not support this. However, it does show that students are enthusiastic about working on authentic science challenges in research teams. The findings, combined with existing literature on curriculum materials, show how curriculum designers can attend to the knowledge, skills, and attitudes of teachers and students and promote the successful implementation of a curriculum with the CBE – 5E pedagogy.

Table of Contents

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1 Introduction

Chemistry education is often considered to be challenging, because concepts are often isolated. In context based education (CBE) there is a strong connection between theory and practice, which makes the content more relevant for students. An authentic context is used as the starting point for learning chemistry concepts. Curriculum materials that are designed for educational reform are often designed with a top-down approach, failing to take into account the teachers and students. The present study examines the knowledge, skills and attitudes of students towards CBE and the 5E instructional model. The obtained data will be used to create guidelines for curriculum designers to create materials that promote the successful implementation of the intended curriculum reform. This chapter describes the background, problem statement, context and goals of the study.

1.1 Background of the study

Many secondary school students consider chemistry to be one of the most challenging subjects of their education. Students consider the material to be isolated, making only weak connections to the real world, which makes chemistry an isolated subject. This causes a passive involvement of students, because they fail to see the relevance of the materials and the importance of chemistry in general (Gilbert, 2006; Osborne & Collins, 2001; Stolk, Bulte, de Jong, & Pilot, 2009). Context-based education (CBE) offers an alternative approach which could help make chemistry concepts more accessible for students. According to Gilbert, Bulte, and Pilot (2011) context-based science education is meant to involve both the contexts in which concepts are used and the relations between those concepts in a more explicit way. The context should be the starting point from which chemistry concepts emerge. Students are likely to be more engaged in meaningful tasks with real-world connections, making them more actively involved in their learning process (King, Bellocchi, & Ritchie, 2008; Stolk et al., 2009). The context should provide “a coherent structural meaning for something new that is set within a broader perspective” (Gilbert, 2006, p. 960).

Within CBE, the learning activities can be organized according to the 5E instructional model, developed by the BSCS (Biological Sciences Curriculum Study). The five phases of learning as described by Bybee et al. (2006) are: Engage, Explore, Explain, Elaborate, and Evaluate (see Table 1). It sequences learning experiences in cognitive stages so that students can construct their understanding of a concept over time, and redefine, reorganize, and elaborate their initial conceptual framework (Bybee & Landes, 1990). The combination of the context-based approach with the 5E instructional model has shown to improve learning results when compared to conventional instruction (Cigdemoglu & Geban, 2015).

Table 1.

Phases of the 5E instructional model

Engage	Engagement in the learning tasks and context.
Explore	Exploration of ideas and material through concrete experiences such as lab activities.
Explain	Concepts, processes, or skills become comprehensible. This process provides the students and teacher with a common use of terms.
Elaborate	Knowledge and skills get extended through involvement in further experiences, which facilitates the transfer of concepts to new, but similar, contexts.
Evaluate	Acquired knowledge and skills are evaluated.

Educational reform requires the design of new curriculum materials. Curriculum materials refer to the resources that are designed to be used by teachers in classroom to guide their instruction (Stein, Remillard, & Smith, 2007). Worldwide, various projects have developed context-based chemistry curriculum materials, such as Salters Advanced Chemistry in the UK (Barker & Millar, 1999; Bennett & Lubben, 2006), Chemistry in Context (Schwartz, 2006) and ChemCom (Sutman & Bruce, 1992) in the USA, Industrial Chemistry in Israel (Hofstein & Kesner, 2006), Chemie im Kontext in Germany (Parchmann et al., 2006), and the Chemistry in Practice in the Netherlands (Bulte, Westbroek, de Jong, & Pilot, 2006). Ball and Cohen (1996) argue that curriculum materials can play four roles in educational reform. Curriculum materials could:

- Help teachers interpret and anticipate what students say and think in response to instructional activities
- Support teachers´ learning of subject matter
- Help teachers consider how curriculum units relate during the year
- Include discussions about particular representations of content to identify the developers´ pedagogical judgments

Additionally, Davis and Krajcik (2005) proposes a fifth role that curriculum materials could play:

- To promote a teachers' pedagogical design capacity, using personal resources and the curricular resources to adapt the curriculum to achieve productive instructional goals

1.2 Problem statement

CBE could be the solution to the isolated nature of chemistry education. Although many context-based chemistry curricula have been designed, they often fail to succeed in practice. In many curriculum reform efforts, there is a lack of coherence between the intended curriculum change and other system components (e.g. teacher development and examination), and the timely and active involvement of relevant stakeholders is often neglected (van den Akker, 2006). Ball & Cohen (1996) argue that curriculum materials can only contribute to professional practice and fulfil the roles described above, if they are created with close attention to processes of curriculum enactment. The enacted curriculum is the result of teachers, students and materials in a particular context.

Curriculum reform often assumes a strong top-down approach, where too little attention is payed to the curriculum enactment process. The role of the teachers is merely considered as ‘executing’ the innovative ideas of others (i.e. curriculum designers). Consequently, the lack of success of a reform is often attributed to the failure of teachers to implement the new curriculum the way it was intended by the developers (Van Driel, Beijaard, & Verloop, 2001). However, Tobin and Dawson (1992) argue that the lack of success is rather the result of curriculum designers failing to take into account the teachers and students. It is generally agreed that for the success of educational reform teachers need to be taken into account (Czerniak & Lumpe, 1996; Duffee & Aikenhead, 1992; Haney & et al., 1996). Van Driel, Bulte, and Verloop (2005) suggest that science education reform efforts have often failed to take teachers’ knowledge, skills and attitudes into account, leading them to be unsuccessful. Bulte et al. (2002) agree that involving teachers and students could increase the perceived relevance of chemistry lessons and could predict implementation difficulties. The implementation of a context-based curriculum remains difficult, because the materials are designed with too little attention to the enactment process. CBE requires teachers and students to adopt significantly different approaches, in which they need to be supported by the materials.

1.3 Context

To address the issue of the isolated nature of science, the Dutch Commission for Science Innovation HAVO and VWO published an advisory report on the outline of the desired nature and content of school chemistry. The commission proposes to use context as an incitement to learning and thinking in concepts ((Driessen & Meinema, 2003). Since the advisory report of the Commission for Science Innovation HAVO and VWO regarding the use of context in chemistry education was published, several pilots have been done to examine the success of context-based modules in the Netherlands. The pilots showed that teachers believed in the relevance and value of the context-based modules, although they questioned its feasibility (Kuiper, Folmer, Ottevanger, & Bruning, 2011).

The present study will be carried out in the context of the Impuls project. The Impuls project is an initiative by the University of Twente in Enschede, funded by the Dutch ministry of Education, Culture and Science. During this two-year project, a teacher design team (TDT) consisting of researchers, secondary school teachers, students and teaching educators, is co-designing a context-based chemistry curriculum for secondary schools. The curriculum includes learning with the 5E instructional model in a context-based setting. Students work in research teams on authentic science challenges, based on current scientific research. The Impuls team wants to design curriculum materials that are useful and relevant to practice.

1.4 GOALS OF THIS STUDY

It has been demonstrated in other studies that CBE fosters a great deal of benefits. However, it has been argued that many attempts at curriculum reform fail, because they adopt a top-down approach that fails to pay close attention to the curriculum enactment. Current research has focused on the effects of context-based materials, with the 5E instructional model, and on identifying the way students and teachers experience specific context-based materials. The present study examines the knowledge, skills and attitudes of teachers and students specifically towards the CBE–5E pedagogy, inspired by current scientific research, within the context of the Impuls project. The findings are used to create specific guidelines for curriculum designers, which describe how context-based chemistry curriculum materials can help foster the knowledge, skills, and attitudes of teachers and students to promote curriculum reform. The empirical data can give insight into how context-based materials can best be accommodated to practice, ensuring a successful implementation of materials using the CBE – 5E pedagogy. Moreover, the conceptual framework will show which knowledge, skills, and attitudes are desirable for teachers and students for the CBE – 5E pedagogy. The findings of this research show the present situation, which could identify possible gaps that need to be bridged.

In the short term, the Impuls design team will benefit from the data obtained in this study. The design guidelines that will be produced can help to ensure a successful implementation of their materials. The study can identify the needs and wishes of students and teachers, and expose possible pitfalls that they might anticipate during the implementation of the materials. By gathering empirical data, specific guidelines can be given regarding the knowledge, skills and attitudes of both teachers and students towards the pedagogical framework of the materials. Consequently, the Impuls design team can customize their materials accordingly. In the long term, other context-based curriculum designers can benefit from the study. Although this research focusses on specific chemistry content, the outputs could serve as an example or raise considerations for the design of materials on other topics. Eventually, the study will benefit the teachers and students who will use the curriculum materials in practice. Furthermore, instruments that are designed in this study could be used to measure the views of teachers and students towards context-based science education using the 5E instructional model. These measurement constructs could be used in future research.

2 CONCEPTUAL FRAMEWORK

The goal of the study is to gain insight into the knowledge, skills and attitudes of teachers and students towards CBE and the 5E instructional model. It will be described which knowledge, skills and attitudes are relevant for teachers and students regarding the CBE – 5E pedagogy according to the existing literature, which will make up the conceptual framework underpinning this study. Teachers' and students' knowledge is conceptualized as recognizing the pedagogical framework, defining its key features (processes), and their experience with the approach. The CBE-related teacher skills that are identified are: context handling, learning regulation, and (re-)design of curriculum materials. Furthermore, the role of the teacher is described for each phase of the 5E instructional model. The relevant teacher attitudes and beliefs are perceived relevance, value congruence, judgments about the success of the reform teaching emphasis and CBE advocate. The CBE-related student skills are related to research skills and self-regulated learning. Regarding the 5E instructional model, the students' role is described for each phase. The relevant student attitudes are motivation and value. An overview of the relevant concepts and their definitions is presented in Table 2 (p. 21)

2.1 CURRICULUM MATERIALS TO PROMOTE REFORM

According to Ball and Cohen (1996) curriculum materials can contribute to professional practice if they are created with close attention to the curriculum enactment processes (teachers, students, and materials). Davis and Krajcik (2005) describe a set of design heuristics for science curricula that promote teacher learning. These heuristics can be useful in promoting curriculum reform as well, because it shows how curriculum materials can support teachers in adopting new teaching methods. Vos, Taconis, Jochems, and Pilot (2010) argue that it is most likely that classroom implementation of new materials will only be successful after explicit or implicit learning by the teacher. In contrast, Davis and Krajcik (2005) suggest that this implicit learning takes place through the implementation of new materials. By involving teachers in the design process, both points of view are accounted for. The design heuristics describe what the materials should provide for teachers, how the materials could help teachers understand the rationale behind the suggested approaches, and how teachers can use these approaches in their own teaching practice.

The design heuristics are focused on teachers' pedagogical content knowledge (PCK), because curriculum materials might be the most successful in promoting teacher learning with regard to PCK as it is mainly acquired through classroom practice (Collopy, 2003; Schneider & Krajcik, 2002). In the present study, teachers' PCK is related to chemistry content and the CBE - 5E pedagogy. Although the chemistry content may vary, the heuristics show how curriculum materials can support teachers in developing knowledge about how they can teach concepts in a CBE – 5E pedagogy.

The design heuristics from Davis and Krajcik (2005), and its application to the CBE – 5E pedagogy, are presented in Table 2. Besides describing what and how to teach, curriculum materials should provide rationales behind the approaches that are provided (Davis & Krajcik, 2005; Vos et al., 2010). These rationales should explain why the suggested approach is scientifically and pedagogically appropriate to help teachers understand the underlying ideas of the pedagogical decisions made by curriculum designers. Furthermore, curriculum materials can provide teachers with implementation guidance. This guidance should consist of clear recommendations for how to use the suggested approaches in practice.

The heuristics can be used to make informed decisions in the curriculum design process. Following these heuristics can promote teacher learning and curriculum reform. However, these heuristics are designed for science curricula in general. In the present study, specific guidelines will be developed for context-based chemistry curricula that are informed by the knowledge, skills and attitudes of teachers and students.

Table 2.

Design heuristics for curriculum materials that promote teacher learning

Knowledge base	**Design heuristic**	**Application to CBE – 5E**
I. PCK for Science Topics	*Supporting Teachers in Engaging Students with Topic-Specific Scientific Phenomena*	Curriculum materials should explain why particular experiences are appropriate and provide teachers with physical experiences that make concepts accessible for students. The materials should include possible pitfalls and describe how the experiments can be used in practice, as demonstrations or independently by students.
	Supporting Teachers in Using Scientific Instructional Representations	Curriculum materials should include a variety of appropriate representations of content (e.g., analogies, models, diagrams) and explain why particular representations are appropriate
	Supporting Teachers in Anticipating, Understanding, and Dealing with Students' Ideas About Science	Curriculum materials should identify the importance of students' ideas. This is especially important for CBE, because of the highly self-regulated inquiry activities. The materials should help teachers identify likely student ideas within a topic and deal with these ideas in their teaching.

II. PCK for Scientific Inquiry	*Supporting Teachers in Engaging Students in Questions*	Curriculum materials should provide driving questions for teachers to elicit student response and explain why particular questions are appropriate. Within the 5E instructional model, teachers need to ask probing questions during the Engage phase, to create interest and curiosity, and identify student's prior knowledge. During the explore phase, these questions should support teachers in creating a 'need to know' setting and guiding students' inquiry.
	Supporting Teachers in Engaging Students with Collecting and Analysing Data	During the explore phase, curriculum materials should provide approaches to help students collect, compile, and understand data and observations. The materials should help teachers understand the importance of evidence in scientific inquiry and how they can adapt and use these approaches.
	Supporting Teachers in Engaging Students in Making Explanations Based on Evidence	During the Explain phase, students should explain concepts and definitions in their own words. Curriculum materials should include recommendations for how teachers can support students in making sense of data and generating explanations based on evidence.
	Supporting Teachers in Promoting Scientific Communication	Within the CBE – 5E pedagogy, students often work in research teams, independent from the teacher. Curriculum materials should explain how teachers can promote students' productive scientific communication (e.g., class discussions, student presentations, lab reports).
III. Subject Matter Knowledge	*Supporting Teachers in the Development of Subject Matter Knowledge*	Curriculum materials should support teachers' factual and conceptual knowledge of chemistry concepts and contexts. The support should be provided on a level beyond the level of

	understanding required by students, making visible the connection to real-world phenomena. The material should include concepts that are likely to be misunderstood by students (i.e. misconceptions).

In addition to the themes in the design heuristics of Davis and Krajcik (2005), Van den Akker (1988) found that teachers faced problems in the implementation of curriculum materials specifically in their lesson preparation and the assessment of learning effects. To support teachers with lesson preparations, curriculum materials should provide an overview and short descriptions of all lessons, a list of required materials and equipment, and a description of the lesson aims and how activities contribute to these aims. Furthermore, teachers should be supported in the assessment of learning effects by offering suggestions for activities and test questions.

Doyle and Ponder (1977) describe the concept of practicality to describe the way in which teachers assess curriculum innovations. To deem an innovation as practical, teachers need to be supported by procedural specifications ('how to do it'), and the innovation should fit the circumstances of the classroom (congruence) and be cost-effective. In this case, cost refers to the time, knowledge, and resources required to adopt the innovation.

Brown (2009) examined the relationship between curriculum materials and teacher practice. He argued that in curriculum materials, there should be multiple points of access. Based on teachers' pedagogical design capacity (being able to assess affordances of the materials and make decisions for its use in practice), teachers should have a choice between pre-authored lessons or assemble their own collections of instructional resources. To allow for adaptations, the materials should emphasize the key building blocks of a lesson, instead of its procedural steps. The instructional resources should be clearly organized by a rationale; however, they should not be so structured that they require any single mode of use.

Curriculum materials can support teachers and students in the enactment of the curriculum, by helping teachers understand the underlying ideas of the pedagogical decisions made by curriculum designers and making clear recommendations for how to use the suggested approaches in practice. The materials can also include support for teachers and students in their development of knowledge, skills, and attitudes that are relevant for a successful curriculum enactment. These concepts will be elaborated further in the following sections.

2.2 TEACHERS

2.2.1 Knowledge

Knowledge is directly related to teachers' behaviour in classrooms and influences the way teachers respond to curriculum change (Verloop, 1992). Therefore, it is a relevant source to draw on for innovators when implementing curriculum changes. Knowledge of pedagogy and subject matter is built up over the course of teachers' careers. According to Van Driel et al. (2001), this knowledge is mainly the result of their teaching experience. As new experiences shape new knowledge, this is considered as an important aspect of this concept. Teaches' knowledge base can be further conceptualized based on Shulman (1987) notion of pedagogical content knowledge (PCK). Shulman described PCK as knowledge of pedagogy that is applicable to the teaching of specific content. Shulman distinguished to main components of PCK: the most meaningful forms of representing the subject matter, and an understanding of what aspects make the learning of these topics easy or difficult. Teachers' PCK regarding the CBE – 5E pedagogy includes an understanding of how this approach influences their teaching and the representation of the subject matter. It also includes knowledge on what difficulties students can experience in a context-based setting. For the purpose of this study, it is important to know if teachers recognize the pedagogical framework, whether they can define its key features (processes), and if they have experienced it in practice. Research has shown that teachers' knowledge and cognitions seem to be able to change if there is sufficient time, resources and on-going professional support available (Appleton & Asoko, 1996; Glasson & Lalik, 1993; Radford, 1998; Tobin, 1993). Curriculum materials could provide the resources and support that teachers need.

2.2.2 Skills

In CBE, and curriculum reform in general, requires teachers to develop a distinct set of skills. De Putter-Smits, Taconis, and Jochems (2013) identified three CBE related skills for teachers: context handling, learning regulation, and (re-)design of curriculum materials.

Context handling

First, teachers need to familiarize themselves with the context that is used in the materials. They need to establish concepts and make them transferable to other contexts. This teacher competency is called context handling. The context should serve as an encouragement for students to explore and learn concepts and to apply them to different situations. The teacher should establish these concepts and be aware of the need for concept transfer (van Oers, 1998).

Learning regulation

Based on the constructivist view on learning, Labudde (2008) described four learning dimensions: the teaching methods, the learning process of the individual, knowledge co-construction through interaction with others, learning as an active process of acquiring new information that is within the horizon of the learner, and. The third and fourth dimension are especially important to consider in CBE, because these include the active learning of concepts within a context. Labudde (2008) argues that to promote learning as an active process and to stimulate the co-construction of knowledge, teaching methods such as student active learning or student self-regulation are the most suitable. These teaching methods require teachers to share the responsibility for learning with their students. Therefore, the teacher's task is to organize, facilitate and guide students' learning process, rather than control it. To achieve a high level of self-regulated learning, teachers are required to apply loose control strategies (Bybee, 2002). Activities that support such a teaching strategy include giving students the opportunity to make connections with their own experiences, make choices in their learning process, take responsibility for their learning and tackle problems together (Vermunt & Verloop, 1999). Avargil, Herscovitz, and Dori (2012) indicated that some teachers struggled with the unorthodox teaching methods, because they were no longer in control of the learning process. Bennett, Grasel, Parchmann, and Waddington (2005) argued that teachers feared that students were not ready for the required level of responsibility.

(re-)Design of curriculum materials

The third teacher competency refers to the (re-)design of curriculum materials. Context-based materials are often not directly suitable for every classroom or the individual learning needs of students. Additionally, because of the active role of the students, unpredictable learning issues may come up that interfere with the initial timetable. Therefore, teachers may need to adapt the materials to fit their classroom's environment and their school's facilities. The need for (re-)designing curriculum materials is more present in CBE than in traditional education and requires more effort from the teacher. Teachers therefore, need to be willing to spend time on adjusting the materials before they implement it in practice. Stolk, De Jong, Bulte, and Pilot (2011) reported that teachers were generally confident and motivated to adapt curriculum materials.

Engage

Bybee et al. (2006) and others described the role of the teacher specifically for each element of the 5E instructional model. During the Engage phase, the teacher assesses students' prior knowledge and helps them to engage in a new concept, by generating interest and curiosity. Short activities can be used to make connections between prior and present learning experiences and to direct students' thinking toward the learning outcomes of the current activity.

Explore

The teacher encourages students to work together on lab activities or investigations, without giving direct instruction. The teacher identifies current conceptions (and misconceptions) and facilitates conceptual change by observing and listening to students and asking probing questions to guide students' investigations when necessary. The students should be provided sufficient time to puzzle through problems. The teacher should create a “need to know” setting, where students are focused on asking ‘what comes next’ (Westbroek, 2005). Stolk et al. (2011) indicated that teachers found this challenging, but dealt with this by carefully guiding student discussions towards the relevant concepts. This corresponds to the cognitive load theory, which argues that new information should be presented ‘just-in-time’ (Kester, Kirschner, van Merriënboer, & Baumer, 2001). Schwartz (2006) also reported that one of the unresolved issues in CBE is related to how one determines how much information and instruction is ‘needed’.

Explain

The teacher focusses students’ attention on a specific aspect of their experiences during the engagement and exploration phase. The teacher encourages students to explain concepts and definitions in their own words, asks for justifications, and encourages students to discuss their definitions. Teachers can also choose to directly explain a concept, process or skill if they feel this is needed. Throughout this phase, the teacher uses students’ previous experiences as the basis for explaining concepts and assesses their students’ growing understanding of the concepts.

Elaborate

The teacher encourages the students to apply or extend the concepts and skills in new situations. He/she reminds the students of alternate explanations and refers the students to existing data and evidence. Whitelegg and Parry (1999) suggest that education should not only aim to teach students definitions of concepts, but also how to apply concepts in contexts, not limited to the contexts they learn in school. This is also refered to as the transfer of concepts. The elaboration phase aims to strengthen the transfer of knowledge and skills. However, Vignouli, Hart, and Fry (2002) indicated that teachers were concerned that students would be unable to transfer their learning and apply concepts in new situations.

Evaluate

The teacher observes the students as they apply the new concepts and skills, assesses the students’ knowledge and skills, and looks for evidence that the students have changed their thinking or behaviours. In traditional education, it is common to assess students with a summative test, which is usually focused on examining content knowledge. In CBE, the goal is for students to develop not only new knowledge, but also higher-order thinking skills (e.g. problem solving skills, inquiry skills) (Birenbaum, 2003; Dori, 2003; Osborne & Millar, 1998). Research has shown that alternative forms of assesment, such as formative testing, can promote the development of such skills (Barak, Ben-Chaim, & Zoller, 2007; Walker & Zeidler, 2007). Bennett et al. (2005) stated that the teachers claimed that context-based examination allows students to think critically, although traditional examination is more clear and easier to organize. Avargil et al. (2012) indicated that teachers viewed the assessment as the greatest challenge in a context-based course.

The 5E instructional model should be considered a cyclic process. It is often necessary to move back and forth between the phases, especially before students are ready to begin the elaboration phase. Bybee (1997) argued that the model is very flexible and dynamic. Withee, Lindell, Heron, McCullough, and Marx (2006) conducted a survey among chemistry and mathematics course instructors, to measure their views on the 5E instructional model. The instructors claimed that although they thought it was a convenient tool in organizing lessons, they found it difficult to separate and interpret the phases. Furthermore, they experienced difficulties with aligning the 5E activities with the desire of students to explore. This indicates there is a gap between the theoretical value of the model and its value in practice.

In this study, it will be examined to what extend teachers believe they are capable of performing the skills that are relevant for the CBE – 5E pedagogy, as their perception of their abilities play an important role in curriculum implementation.

2.2.3 Attitudes

Teachers' attitudes play a significant role in the success of a curriculum. Several categories of attitudes can be distinguished in relation to curriculum reform: perceived relevance, value congruence, and judgments about the success of the reform. Besides these attitudes, there are two beliefs that influence teachers' attitudes toward curriculum reform, and more specifically CBE: teaching emphasis and CBE advocate.

Perceived relevance

The first attitude that plays a role in the success of curriculum reform is the teachers' perceived relevance of the reform. The teacher should recognize the relevance of the reform regarding its effect on the teaching-learning process. If teachers do not believe that the reform has a positive effect on this process, or might even negatively affect it, they will be reluctant to implement the reform (Vos et al., 2010).

Value congruence

There also needs to be a significant overlap between the teacher's belief system and the new curriculum about what a 'good practice' is, also known as value congruence (Bennett et al., 2005; Harland & Kinder, 2014; Vos et al., 2010). Value incongruence can negatively influence the decision of teachers to implement the new curriculum.

Judgments about success

Based on their perceptions of the effect on student learning and attitudes, teachers will have judgments about the success of a new curriculum (Bennett et al., 2005). These judgments are critical to decisions about engagement in change. If teachers do not believe in the success of a curriculum innovation, they will be hesitant to become involved. Bennett et al. (2005) indicated that although teachers were positive about context-based teaching in general, they felt that specific concepts might be missed**.** These perceptions can have a significant effect on the teaching. The teachers that were involved in the Chemie im Kontext study expressed that their syllabi and freedom of choice for topics and activities were the key factors that determined the success of the implementation of an innovation. Additionally, they stressed the importance of adequate equipment of their schools, which need to be suited for the type of activities used in CBE (Parchmann et al., 2006).

Teaching emphasis

It has been argued that teachers' beliefs influence the way they interpret and integrate new curriculum materials (Pajares, 1992). In relation to the CBE – 5E pedagogy, two beliefs can be distinguished: teaching emphasis and CBE advocate. Van Driel et al. (2005) described three teaching emphases for chemistry education: Fundamental Science (FS) where the emphasis is placed on understanding theoretical concepts; Knowledge Development in Science (KDS) which places emphasis on learning to view science as a culturally determined system of knowledge; and Science, Technology and Society (STS) which emphasizes teaching students to communicate and make decisions about social issues involving scientific aspects. In a study by Van Driel et al. (2005) teachers mostly supported an FS emphasis, because it focusses on introducing students to fundamental concepts and skills within chemistry. Avargil et al. (2012) observed that teachers with an FS emphasis made little effort to relate concepts to everyday life. It has been argued that an emphasis on KDS or STS is the most successful in CBE, because this goes beyond the teaching of basic concepts.

CBE advocate

The second teacher belief relates to school innovation. If the school does not support the context-based innovation, it will not succeed. Therefore, teachers should be willing to advocate for CBE within their school. The teachers who were involved in the development of 'Chemie im Kontext' (ChiK), expressed a wish for more collaboration between colleagues to create a coherence in the curriculum (Parchmann et al., 2006).

2.3 STUDENTS

2.3.1 Knowledge

Similar to teachers, students' knowledge also influences the way students respond to curriculum change. Throughout their school career, students experience different types of curricula, through which they build up knowledge of instruction and a variety of learning strategies. In the present study, it is examined whether students recognize the pedagogical framework, whether they can define its key features, and if they have experienced it in practice. Much like with teachers, it can be expected that students who have more experience with CBE, have more knowledge about their role as students and the way they learn in this approach.

2.3.2 Skills

For this study, the goal is to examine the self-perceived skills of students regarding the CBE – 5E pedagogy. The two student skills related to context-based learning that stand out are related to research skills and self-regulated learning.

Research skills

Schwartz (2006) indicates that context-based pedagogy focusses on a student-centred activities and inquiry-based laboratory investigations. Students will have more freedom to explore materials and ideas and to conduct their own investigations. They will need research skills to carry out these investigations successfully and to draw reasonable conclusions based on collected evidence.

Self-regulated learning

Another key feature of CBE is that the activities involve a high level of self-regulated learning. Learning activities that support self-regulation can include small-group discussions, problem-solving tasks, laboratory investigations and role-play exercises (Bennett et al., 2005). Gilbert (2006) expresses that in a context-based setting, students often work independent from the teacher and have more control over their learning process. Therefore, students are required to develop a sense of ownership and responsibility of their learning, which leads to a higher sense of achievement and increase in self-confidence (Bennett et al., 2005; Potter & Overton, 2006). Even when experiments produce incorrect results students will feel a sense of control over their learning process, which improves their self-efficacy (Osborne & Collins, 2001). Students should be allowed to make decisions in their learning process, within pre-set limits (De Putter-Smits, Taconis, Jochems, & Van Driel, 2012). Gilbert (2006) suggests that the combination of self-directed learning and the use of contexts promotes students to construct their own meanings from their experiences, rather than acquiring knowledge from other sources.
By sequencing the learning with the 5E instructional model, students are guided through this process.

Engage

Bybee et al. (2006) described that during the engagement phase students should ask questions such as, “Why did this happen?” “What do I already know about this?” “What can I find out about this?”. The context should encourage students to become engaged in the topic while keeping an open mind.

Explore

The explore phase includes the main inquiry-based activity, such as laboratory investigations. Students should think freely while exploring ideas and possibilities. Students will test predictions and hypotheses during investigations. Students are given a hands-on experience of exploring the concepts prior to receiving the explanation, which will deepen their understanding. It is important that students stay open-minded and consider alternative solutions, so that they will not establish misconceptions.

Explain

Students should try to explain possible solutions or answers in their own words and discuss these with their classmates. During the discussions, they should listen critically to alternative explanations proposed by their peers. If the teacher provides direct explanations of concepts, the students will listen and try to comprehend these explanations. Throughout this phase, the students will refer to previous activities and assess their growing understanding.

Elaborate

During the elaboration phase, students will learn how to apply new labels, definitions, explanations, and skills in new but similar situations. They will use previously attained information to ask questions, propose solutions, make decisions and design experiments. It is important that students know how to draw reasonable conclusions from evidence, so they can connect previous and new information to develop coherent mental maps of the chemistry concepts.

Evaluate

To demonstrate their understanding of the new concepts or skills, students answer open-ended questions by using observations, evidence and previously accepted explanations. Additionally, the students evaluate their own progress and knowledge and ask related questions that would encourage future investigations.

2.3.3 Attitudes

Many studies have examined what determines students' attitude towards (learning) science. Based on several measurement scales and questionnaires, the following components can be defined (Aydeniz & Kotowski, 2014; Osborne, Simon, & Collins, 2003; Tuan, Chin, & Shieh, 2005).

Motivation

Students' interest and enjoyment of science. Research has shown that working in a context-based setting improves students' attitudes to school science and science in general (Ultay & Calik, 2012). It improves students' motivation, enthusiasm and attitudes towards chemistry (Demircioglu, Demircioglu, & Calik, 2009). Students interest is greater when school work includes opportunities for experimentation and investigation (Osborne & Collins, 2001).

Value

By working on science challenges that make connections between real life and science concepts students claim to view chemistry as more relevant to their lives (Bennett, Hogarth, & Lubben, 2003; Osborne & Collins, 2001; Ultay & Calik, 2012). CBE offers a possibility to bring real life experiences into the classroom, making the content more meaningful. Once students recognize the value and relevance of the materials, their enthusiasm towards chemistry increases as well (Ultay & Calik, 2012). Wu (2003) argued that students learn more holistic representations of concepts, because they collect information from multiple sources in addition to the teachers' lecture or textbook.

2.3.4 Summary

The previous sections have discussed how curriculum materials can promote reform, and the relevant knowledge, skills, and attitudes of students and teachers towards the CBE – 5E pedagogy according to the existing literature. Curriculum materials can be designed to support teachers and students in the development of these relevant knowledge, skills, and attitudes, so they can successfully implement the materials. Table 3 provides a summary of the conceptual framework.

Table 3.

Definitions of the relevant concepts

	Teachers	**Students**
Knowledge	Do they (1) recognize it, can they (2) define it, have they (3) experienced it?	
Skills	*Context handling.* Familiarize with the context. Establish concepts and make them transferable.	*Research skills*. Conducting investigations, drawing reasonable conclusions based on collected evidence.
	Learning regulation. Share responsibility for learning with students, apply loose control strategies.	*Self-regulated learning*. Active and self-directed learning. Having a sense of ownership and responsibility of the learning process.
	(re-)design of curriculum materials. Adapting curriculum material according to the learning environment and the needs of learners.	*Engage.* Show interest in the topic and think actively
	Engage. Assesses prior knowledge, engage students, generate interest and curiosity	*Explore.* Perform laboratory investigations, think freely, stay open minded and consider alternative solutions
	Explore. Identify current (mis-)conceptions and facilitate conceptual change, ask probing questions, create a 'need to know' setting, provide just-in-time information	*Explain.* Explain possible solutions in their own words, discuss alternatives with classmates and listen critically
	Explain. Focus students' attention, use multiple approaches to generate explanations based on evidence	*Elaborate.* Use previously attained information to ask questions, propose solutions and make decisions, draw reasonable conclusions from evidence
	Elaborate. Facilitate transfer of concepts, remind students of alternative explanations	

	Evaluate. Assess students' knowledge and (higher-order thinking) skills	*Evaluate.* Answer open-ended questions, use observations and evidence
Attitudes	*Perceived relevance. Re*cognize the relevance of CBE regarding its effect on the teaching-learning process.	*Motivation*. Interest and enjoyment of science.
	Value congruence. A significant overlap between the teacher's belief system and CBE about what a 'good practice' is.	*Value*. Recognize the value and relevance of the curriculum materials.
	Judgments about success. Judgments about the success of CBE in practice.	
	Teaching emphasis. Emphasis on FS, KDS or STS.	
	CBE advocate. Being willing to act as a representative for CBE.	

2.4 Research questions

Teaching with the context-based approach, using the 5E instructional model, has a clear theoretical value. However, it could be argued that the theoretical value of the pedagogical framework is not always sustained in practice. To design a curriculum that will be relevant and useful in practice, empirical data will be collected to gain insight into the knowledge, skills, and attitudes of teachers and students regarding the proposed pedagogical framework. These insights will be used to create specific design guidelines for a CBE – 5E curriculum. This research will attend to the following question: *How can curriculum can curriculum materials help foster the knowledge, skills and attitudes of teachers and students towards teaching and learning with the 5E model in a context-based chemistry curriculum inspired by current scientific research?* The following sub questions will be answered. The answer to the sub questions will result in guidelines for curriculum designers.

SQ 1. What are the knowledge, skills and attitudes of teachers towards the pedagogical framework used in the proposed chemistry curriculum?

SQ 2. What are the knowledge, skills and attitudes of students towards the pedagogical framework used in the proposed chemistry curriculum?

3 Research method

The focus of this chapter is to describe the methods used in this study to answer the research questions. First, the overall research design will be discussed. Next, the respondents, instruments, procedure and data analysis will be described in more detail. The study adopted a mixed-methods approach. Qualitative exploratory research was conducted to provide in-depth information. This included a focus group with expert teachers and group interviews with teachers and students. The knowledge, skills and attitudes of teachers and students were explored further through quantitative data in the form of questionnaires.

3.1 Research design and model

This study involved a mixed-methods approach. In-depth information has been generated by qualitative exploratory research. Informed by these findings, the knowledge, skills and attitudes of teachers and students have been explored further through quantitative data on a larger scale. These findings have been combined and analysed within the context of the conceptual framework to produce a set of design guidelines for curriculum designers. The research design is descriptive in nature, the goal was to explore the views of teacher and students and to discover patterns. The research model is depicted in figure 1; the outcomes of each data gathering activity influenced the approach to the next activity, and all three data sources were used to produce the design guidelines.

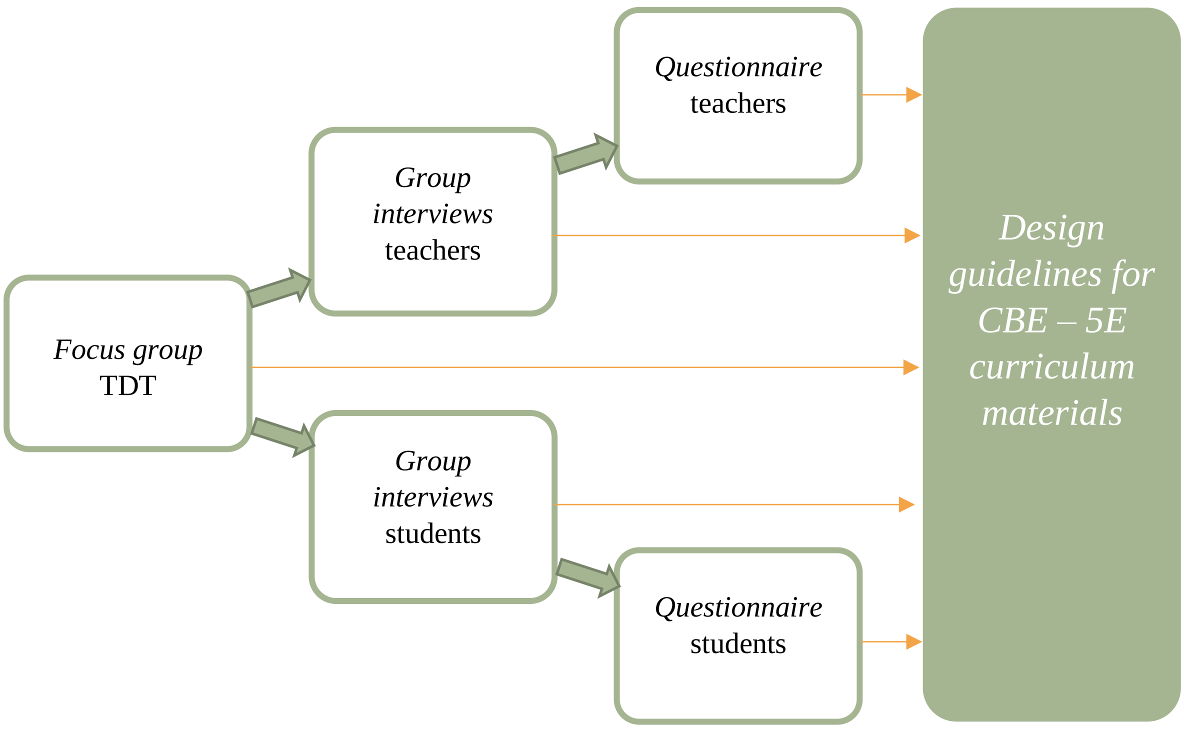

Figure 1. Research model

3.2 Respondents

The first step in the data gathering was a focus group with expert teachers. The focus group included the 10 secondary school chemistry teachers from the TDT. These teachers were considered to have relatively expert knowledge of CBE and the 5E instructional model as they were closely involved with the Impuls design process.

Two sets of group interviews were organized; for teachers and for students. The target populations of the study fourth and fifth grade VWO chemistry teachers and students. Six secondary schools were selected based on their level of experience with innovative chemistry modules. Two schools were selected for each condition: low (0-2 modules used), moderate (3-5 modules used) or high level (6 or more modules used) of innovation experience. From these six schools, the teachers and students were selected. The schools had two or three higher level VWO chemistry teachers in their department, who were all asked to participate. The student group interviews consisted of four to five students from level 4 or 5 VWO. This amount was chosen to prevent students to be hesitant to participate in the group discussion. Only 20% of the students who participated in the group interviews were male. This unequal distribution is the result of sampling based on convenience; the teacher often asked which students would voluntarily participate in the interview.

The questionnaire was distributed among 250 Dutch upper level VWO chemistry teachers, out of which 87 teachers participated. For this data collection activity, no distinction was made between the level of innovation experience of the respondents. The level of innovation experience is associated with the school. The respondents of the questionnaire did indicate whether they had experience with the CBE -5E pedagogy, however this is not the same as innovation experience. At the end of the questionnaire, the teachers could indicate whether they were willing to let their students fill out a questionnaire during class as well. Fifteen teachers responded positively and as a result 107 students filled out the questionnaire. The participants were asked to provide their demographics. Table 4 shows the descriptive statistics for the participants. The level of innovation experience is not provided for the respondents of the questionnaire, because they were not classified according to their school.

Table 4.

Descriptive statistics of respondents

	TDT	Group interviews	Questionnaire
Teachers	(N = 10) %	(N =13) %	(N =87) %
Age			
20-30	0	8	13
31-40	0	0	17
41-50	16	46	42
50<	84	46	28
Years of teaching experience			
1-6	0	15	16

7-10	0	23	17
11 or more	100	62	67
Innovation experience			
Low (0-2)	0	38	-
Moderate (3-5)	0	31	-
High (5 or more)	100	31	-
Students	-	(N = 15)	(N = 107)
Grade and level			
4 VWO	-	16	11
5 VWO	-	84	89
Innovation experience			
Low (0-2)	-	32	-
Moderate (3-5)	-	32	-
High (5 or more)	-	36	-

3.3 Instrumentation

To collect the data to answer the research questions, three instruments were used. The qualitative data collection consisted of a focus group with expert teachers, and group interviews with teachers and students. For the quantitative data, a questionnaire was used to examine whether the initial findings could be quantitated by a larger sample. The goal was to get insight into teachers' and students' self-perceived knowledge, skills, and attitudes. Although knowledge and attitudes are constructs that can be adequately measured by self-report, the self-report measurement of skills is more difficult. Regarding their skills, the respondents were asked to make an estimate of their ability to perform the skills regarding the CBE – 5E pedagogy. The three instruments all contributed to the examined concepts. Although the questionnaire only contributed to the concept of knowledge in the form of experience with the CBE – 5E pedagogy. It was not considered an appropriate instrument to measure the respondents' ability to recognize or define the proposed pedagogical framework, because the instrument only allows for closed-ended questions. The contribution of each instrument is illustrated in Table 5.

Table 5.

Instruments matrix

	Focus group	Group interviews	Questionnaire
Knowledge	+	+	+/-
Skills	+	+	+
Attitudes	+	+	+

Focus group discussion

The teacher experts from the TDT were asked to participate in a focus group. During the focus group, the participants were asked to respond to several open-ended questions regarding their knowledge, skills and attitudes towards the pedagogical framework. The TDT focus group was used to gain insight into the perspectives of expert teachers. Furthermore, the findings of the focus group were used to further refine the instrument for the group interviews. The first question that was asked during the focus group was: “What is your perception of the context-based approach in general?”. The discussion took place quite naturally, because the teacher experts had a lot of insights they wanted to share. Some additional questions were asked to steer the discussion towards certain aspects of the pedagogical framework, such as “To what extend do you believe the elaboration phase adds value to the learning process?”. Drawing from their experience with CBE and innovative curriculum materials in general, the expert teachers could provide a lot if insights regarding the implementation of context-based curriculum materials. To check if the participants felt their perceptions were represented correctly, a member check was performed with a summary of the findings.

Group interviews

To get more insight into the knowledge, skills, and attitudes of teachers and students, semi-structured group interviews were held. The interviews were more structured than the focus group discussion, because the goal was to get more specific information. The questions were based on the concepts that emerged from the literature, further refined by the outcomes of the TDT focus group. interview included questions such as “To what extend does the context-based approach match your own ideas about good education and what is relevant for your students?” and “To what extend would you be willing to spend extra time on adjusting the materials, based on the learning needs of your students?”, and for students: “Do you believe you are able to draw conclusions based on what you observed in your investigations?”. An overview of the operationalization, including example questions, is presented in Table 6.

Questionnaire

After the concerns of teachers and students were recognized, two separate questionnaires were developed for the teachers and the students to further explore the concepts. Moreover, the questionnaire was conducted to see if the findings from the group interviews could be substantiated by a larger sample. The questions were based on the findings of the group interviews and could be answered on a Likert-scale ranging from (1) “strongly disagree” to (5) “strongly agree”. The questionnaire included questions such as “I think it is important that students experiment with ideas and materials before they receive the explanation” (teachers) and “I think I would find it confusing to perform experiments before I know details about the topic, because I will not know what to look for” (students). These examples illustrate that the questions were specifically composed based on the initial findings of the interviews, as many teachers and students made these statements. The goal of the questionnaires was to test if the tentative conclusions from the focus group and interviews were more broadly applicable to a larger sample. The teacher questionnaire was tested by the expert teachers from the TDT. They were asked to comment on the general structure of the questionnaire and to make suggestions about the improvement of specific items. The questionnaires were further tested for its validity and reliability during a small pilot with preservice teachers and secondary school students. The pilot lead to a small number of changes in the formulation of the questions. Most importantly, the students reported that some of the questions contained too much formal language, which made it difficult to understand. The second versions of the questionnaires were tested on their reliability (Cronbach's Alpha). The teacher questionnaire showed to be highly reliable (26 items; $\alpha = .85$), as well as the student questionnaire (25 items; $\alpha = .82$). The definitive questionnaires can be found in Appendix B.

3.4 Procedure and data analysis

3.4.1 Qualitative data

The TDT focus group took place during one of their monthly meetings. The group interviews took place on the respective schools. Both activities took approximately 45 minutes. Before the questions about the 5E instructional model were asked, the teachers and students were given a handout that included a summary and an example application of the model. The handouts are presented in Table 10 and 11 in Appendix A.

The data gathered from the TDT and group interviews were analysed with Atlas.ti. The analysis was initially done by deductive coding based on the concepts that were presented in chapter 2. After that, several codes were added through inductive coding. To establish an inter-rater agreement (Cohen’s Kappa), a second researcher was asked to independently code 20% of the data. For the coding of the data related to teachers, an inter-rater agreement of 0.53 was reached during the first try. As this was not satisfactory, changes were made to the codebook. For example, the definition of context handling did not describe clearly enough that this was specifically related to how the teacher dealt with teaching in a context, and nothing else. Because of this, fragments were mistakenly coded as ‘context handling’, when in fact it should have been ‘context-concept generic’. The second try resulted in an inter-rater agreement of 0.71. For the coding of the data related to students, an inter-rater agreement of 0.77 was reached on the first try.

3.4.2 Quantitative data

The teacher questionnaire was distributed via email. The teachers who indicated they were willing to let their students fill out a questionnaire as well, received an email with the link to the student questionnaire. They were asked to distribute the link to 4th or 5th year VWO students during class and let their students fill out the questionnaire on their laptop or smartphone. Both questionnaires included an introduction that briefly explained the purpose of the study and the concept of CBE and the 5E instructional model. The data from the questionnaires was analysed in IBM SPSS Statistics for descriptive statistics to examine whether the findings from the group interviews could be substantiated. Furthermore, one-way analysis of variance (ANOVA) was used to determine whether there are any statistically significant differences between the means of groups based on the level of experience with innovative (or context-based) chemistry curricula. This way, it could be determined whether the level of experience had any significant impact on the way respondents perceived their skills and attitudes.

Table 6.

Operationalization of concepts

	Concept	Definition	Example Question
	Teachers		
Knowledge		Do they (1) recognize it, can they (2) define it, have they (3) experienced it?	Have you taught with context-based modules before?
Skills	Context handling	Familiarize with the context. Establish concepts and make them transferable.	Do you think you can teach concepts within a context that you are still unfamiliar with?
	Learning regulation	Share responsibility for learning with students, apply loose control strategies.	Do you feel you can teach by guiding, supporting, and facilitating students, by applying loose control strategies?
	(re-)design of curriculum materials	Adapting curriculum material according to the learning environment and the needs of learners.	Do you feel capable of adjusting curriculum materials in a flexible manner when this is necessary?
	Engage	Assesses prior knowledge, engage students, generate interest and curiosity	Do you think you can engage students in the topic with the use of a scientific research context?
	Explore	Identify current (mis-)conceptions and facilitate conceptual change, ask probing questions, create a 'need to know' setting, provide just-in-time information	Can you guide students through the process of exploring, without giving direct instruction?
	Explain	Focus students' attention, use multiple approaches to generate explanations based on evidence	Do you think you can encourage students to generate their own explanations?
	Elaborate	Facilitate transfer of concepts, remind students of alternative explanations	Do you think you can make connections between concepts visible for students?
	Evaluate	Assess students' knowledge and (higher-order thinking) skills	Do you think you can assess students' knowledge and skills through alternative (context-based) forms of testing?
Attitudes	Perceived relevance	Recognize the relevance of CBE regarding its effect on the teaching-learning process.	Do you believe that CBE will have a positive effect on the teaching-learning process?
	Value congruence	A significant overlap between the teacher's belief system and CBE about what a 'good practice' is.	To what extend does the context-based approach match your own ideas about what good education is, and what is relevant for students?
	Judgments about success	Judgments about the success of CBE in practice.	Do you believe it is feasible to teach chemistry with the CBE – 5E pedagogy?
	Teaching emphasis	Emphasis on FS, KDS or STS.	Do you believe that the emphasis in chemistry education should be teaching the theoretical understanding of chemistry concepts

	CBE advocate	Being willing to act as a representative for CBE.	To what extend would you be willing to act as a representative for CBE within your school?
	Students		
Knowledge		Do they (1) recognize it, can they (2) define it, have they (3) experienced it?	Have you learned chemistry within the context of current scientific research before?
Skills	Research skills	Conducting investigations, drawing reasonable conclusions based on collected evidence.	Do you think you can draw reasonable conclusions based on what you observed during investigations?
	Self-regulated learning	Active and self-directed learning. Having a sense of ownership and responsibility of the learning process.	To what extend do you think you can make choices in your learning process?
	Engage	Show interest in the topic and think actively	Would you think actively about what you already know about the topic?
	Explore	Perform laboratory investigations, think freely, stay open minded and consider alternative solutions	How would you feel about doing exploring investigations before you know details about the topic?
	Explain	Explain possible solutions in their own words, discuss alternatives with classmates and listen critically	Would you be able to explain a concept in your own words?
	Elaborate	Use previously attained information to ask questions, propose solutions and make decisions, draw reasonable conclusions from evidence	Would you be able to make connections between concepts and new (but similar) contexts?
	Evaluate	Answer open-ended questions, use observations and evidence	Do you feel you can demonstrate your knowledge and skills through open-ended questions?
Attitudes	Motivation	Interest and enjoyment of science	Do you believe that the context-based approach will make chemistry more enjoyable?
	Value	Recognize the value and relevance of the curriculum materials.	Do you believe that it will be easier to recognize why you learn chemistry, because concepts are explained within a concrete context?

4 FINDINGS

In this chapter, the combined findings of the focus group, group interviews and questionnaires will be discussed for the research question. The two sub-questions focus on providing insight into the existing knowledge, skills and attitudes of teachers and students toward the proposed pedagogical framework. The results show that teachers have many of the desired knowledge, skills, and attitudes toward the CBE – 5E pedagogy, as they have been described by the existing literature. They do struggle with the unorthodox teaching methods and express some judgments about the success of a context-based curriculum, such as the challenge to determine when just-in-time information is needed. In contrast, the students have less knowledge of the proposed pedagogical framework. They are relatively confident of their context-based skills, but stress the importance of sufficient structure and guidance. Not all students believe that the CBE – 5E pedagogy will increase their motivation and enjoyment of chemistry, but they are enthusiastic about working on authentic science challenges in research teams. The combined findings of the qualitative and quantitative data are presented in Table 7 (p. 37) for the teachers and Table 8 (p. 43) for the students.

4.1 TEACHERS

4.1.1 Knowledge

All the teacher experts have experience with teaching with a context-based module, but not by the 5E model. They do recognize the sequence of the activities that are defined in the model. All teachers from the group interviews recognize the context-based approach and can define its underlying principles. They understand how this approach has implications for the way they present the chemistry content to their students. They are also aware that the new chemistry curriculum in Dutch secondary schools is based on this approach, although they feel like it still only touches the surface of what context-based teaching should be. In their course book, a context is often introduced in the beginning of a chapter, but it only serves as an introduction. The questionnaire shows different results: 58 % of the teachers have little to no experience with context-based modules (0-2 times), 21 % has some experience (3-5 times) and 20 % has a lot of experience (6 or more times). As can be seen in Table 7, few teachers have experience with the 5E instructional model, which is substantiated by the questionnaire (mean = 1.65). The interviewed teachers indicate that they do recognize the sequence of the phases. One teacher calls it the "Volkswagen Golf you always do in teaching". Additionally, they can define the most important principles that underlie the model, such as the ´need to know´ principle.

It was examined whether teachers' skills and attitudes were influenced by their experience with innovative chemistry curricula. There was only a statistically significant difference between the groups, based on level of experience, for the confidence to adjust curriculum materials. This difference was determined by one-way ANOVA ($F(2,84) = 7.210$, $p = .001$). A Tukey post hoc test revealed that teachers who were inexperienced with innovative chemistry modules were significantly less confident of their ability to adjust modules (3.75 ± 0.28, $p = 0.001$) than the teachers who were experienced with innovative chemistry modules ($4,59 \pm -0.51$). There were no statistically significant differences between the moderately experienced teachers and the inexperienced ($p = 0.152$) and highly experienced ($p = 0.262$). This means that teachers who often work with chemistry modules as a substitute for the course book feel more competent to adjust materials. However, experience has no further relation to teachers' knowledge, skills, and attitudes regarding the CBE - 5E pedagogy.

4.1.2 Skills

Context handling. In CBE, teachers need to familiarize themselves with the context that is used in the materials. Teaching in the context of current scientific research is something that appeals to all teachers. Table 7 shows that the questionnaire supports this statement (mean = 4.03). The teachers are willing to take the time to get familiar with the scientific research as a context to prepare for their lessons. Subsequently, the questionnaire shows the same results on average (mean = 3.84). However, some teachers can think of certain preconditions, as one teacher argues:

> "If it is a module with a clear teacher manual, with information about where we can read up on the subject and context, then it would be quite fun to do".

Learning regulation. CBE requires teachers to apply loose control strategies, by organizing, facilitating and guiding students' learning process. Many teachers struggle with the unorthodox teaching methods involved in CBE. The interviewed teachers with a high level of innovation experience are used to teaching in a context-based setting. They know that this approach requires them to mostly guide and facilitate students and they feel they are competent enough to do this well. The other interviewed teachers claim they prefer to be in control of the learning process. One teacher suggests:

> "If I look at students from 4 VWO, I think they are still very playful and childlike. They will have a lot of freedom here and I am not sure if they can handle that".

Table 7 shows that the questionnaire does not clearly substantiate that teachers are confident of their ability to apply loose control strategies (mean = 3.21), or that they believe it is good that students have shared responsibility over the learning process (mean = 3.58).

Giving plenary class explanations and using formal teaching strategies is important to most teachers, because it is their way of ensuring that all students reach the same level of understanding. Table 7 shows that the questionnaire substantiates these findings (mean = 3.92). However, all interviewed teachers agree that it depends on the difficulty of the topic whether students can handle the shared responsibility of the learning process. Most teachers agree that the materials should provide clear directions for the students, so that they know what is expected of them. One of the teachers with a moderate level of innovation experience claims:

> "The problem with chemistry is that at one point you have to go from macro to micro level and that is quite a big step. That is different from physics, where experiments will lead you directly to a main law".

(re-)Design of curriculum materials. Context-based curriculum materials may need adjusting to fit the classroom's environment and school's facilities, as well as the needs of the learners. Most of the interviewed teachers are aware of the potential need to adjust the materials to fit their practice, as this is the case in traditional teaching methods as well. The teachers with moderate to high level of innovation experience claim they are sufficiently competent to do this and see no real challenges. From the teachers with little innovation experience, three claim they are willing to adapt the materials if there is a sufficiently clear foundation to work with. The other two teachers are not willing to spend additional time and effort on this, which is the main reason why they chose against using chemistry modules in the past. One of these teachers claims:

> "You need to spend so much time on adjusting the materials that I would rather choose for the safe way and work with the course book."

The questionnaire demonstrated that most teachers feel sufficiently competent to adjust curriculum materials based on their teaching practice and the learning needs of their students (mean = 3.98). Regarding their willingness to adjust curriculum materials, teachers were more divided (mean = 3.08).

Engage. In general, teachers are confident that they possess the skills that are necessary to teach with the 5E instructional model, although they believe some phases are easier to implement than others. Table 7 shows that most interviewed teachers see no real challenges in engaging students in the topic, when teaching by the 5E instructional model, which is supported by the questionnaire (mean = 3.21). However, some interviewed teachers argue that for students to become engaged, it is important that the materials are written on a student-level.

Explore. The expert teachers state there is little control over the learning process of students and the results of this will not be seen until the final assessment. A possible way to deal with this hurdle is to ask the groups to keep a logbook where they write about their process, also making free-riding less probable. However, they claim it remains a challenge to ensure all students will reach the same level and understand the concepts equally if they explore the materials independently. Most teachers are aware of the need to create a need-to-know setting and feel they can accomplish this. The teachers from the questionnaire are relatively positive about their ability to determine when they should provide their students with just-in-time information to sustain this setting (mean = 3.85).

Explain. As argued above, teachers prefer giving plenary class explanations to ensure that all students reach the same level of understanding. However, this does not mean that they do not feel competent enough to perform other activities to get students to generate their own explanations. One teacher suggests:

> "We already do that in the last chapters; we will let them explain it to each other and they can do that just fine."

Furthermore, several interviewed teachers wonder when the Explain phases should start and how long you let the students explore on their own.

Elaborate. The teachers consider the elaboration phase the most difficult phase to implement. The main challenge is getting students to see the connection between concepts and making these concepts transferable to other contexts. The questionnaire shows that on average, teachers felt relatively competent to make these connections visible for students (mean = 3.60). The interviewed teachers claim that students should have a solid understanding of the concepts before they can succeed in this phase. The teachers express several concerns related to context-based evaluation. However, these concerns are unrelated to their competency as teachers to perform these types of evaluations.

Evaluate. On average, they do not believe it is easy to perform context-based assessments, such as presentations, exhibitions or research reports (mean = 2.52). One of the teachers with a moderate level of innovation experience explains:

> "I struggle with that, because of two reasons. The first reason being that it is easier to assess with a formal test than it is to revise a whole report, but maybe that is my lazy side. The second reason is that a group of students will hand in a report, but you will need to have done a lot of formative testing to ensure that all students master the subject on the same level."

Only the teachers with a high level of innovation experience believe that it is feasible to perform context-based assessments.

4.1.3 Attitudes

Perceived relevance. The teachers all agree that context-based learning is a valuable and relevant teaching approach. Most of the interviewed teachers express that they would be willing to use a context-based module in their teaching, which the questionnaire supports (mean = 3.35). Only two of the thirteen interviewed teachers indicate that they still prefer teaching with a traditional approach, because they feel that important concepts may be missed in a context-based approach. The teachers from one of the schools with a moderate level of innovation experience argue that their current course book is of sufficient quality and they do not see the added value of a context-based module. The other teachers agree that the context-based approach offers certain benefits that traditional methods lack. For example, one teacher claims:

> "The questions on the national final examination always start from a context, they are very descriptive. When you can start practicing that in the fourth year that will give you an advantage of course".

Most of the interviewed teachers perceive the 5E instructional model as relevant. The questionnaire however, does not support this (mean = 2.88). Several interviewed teachers indicate that each phase the model should be deliberately used because of its added value to the learning process, as opposed to going through the phases because it is required. Many of the interviewed teachers express that they find it important that students explore materials independently before receiving the explanation. The questionnaire shows that teachers were divided in their opinion on this matter (mean = 3.05). Several teachers express that they believe more effective learning takes place when the explanation of the subject matter comes after the explore phase, because students can better relate the information to what they observed during their experiments. Table 7 shows that the questionnaire confirms this (mean = 3.61).

A small group of teachers fails to see the relevance of the elaboration phase. They believe that students will develop a sufficient understanding of the concepts during the other phases. One of the teachers with a low level of innovation experience claims:

> "Maybe it should a step that is meant for students who stand out from the masses. If you have a student that is very gifted, you can give him the extra challenge. The first phases may be sufficient for students who are more or less average"

The questionnaire also shows that most teachers perceive the elaboration phase as relevant (mean = 4.28). The teachers with a high level of innovation experience previously performed context-based assessments and are quite positive about evaluating through presentations, exhibitions or research reports. They also indicate that students practice other relevant skills, such as presenting, creativity, and research and writing skills. The questionnaire demonstrated that teachers were not really enthusiastic about context-based assessments (mean = 2.98).

Value congruence. Most teachers agree that there are important benefits of teaching with the context-based approach. They feel that it encourages students to think actively and be more engaged in the topic, and it would help them to understand the relevance of the topic. The teachers express that they believe these are important aspects of teaching. One of the teachers argues:

> "It is good when a student realizes why he is learning what he learns. If you start with why are you learning this, and then you get deeper into the topic, that works for both parties".

The questionnaire showed that on average, teachers slightly agreed that there was a significant overlap between the context-based approach and their personal beliefs about what a good practice is (mean = 3.53).

Judgments about success. Overall, most teachers believe in the success of the CBE – 5E pedagogy, although they express some concerns regarding the implementation. The expert teachers claim that there are several factors that are crucial to the success of a context-based curriculum: the vision of the school towards educational reform, the level of the students (HAVO or VWO), and the difficulty level of the specific context. Furthermore, there should be a clear cohesion between the context and the concepts. The teachers argue that there should be enough practice exercises for the students to process the concepts, and attention should be paid to how the concepts are made clear afterwards (e.g. a glossary, summary).

Most interviewed teachers believe that the context-based approach is feasible, except for two teachers who believe there is not enough time to implement such a method. The questionnaire showed that teachers were divided in their opinion of the feasibility of CBE (mean = 3.34). Several practical concerns were expressed by the interviewed teachers regarding to the success of a context-based curriculum. First, they stress that the materials should be coherent with the existing curriculum. To prevent teachers from having to spend extraneous time to investigate how the context-based module fits in to their current curriculum, it should be clear which concepts are treated in the module and which parts of their course book can be replaced by the module. Several teachers say that if this is not clear, it is unlikely that they will use the materials. One teacher suggests:

> "When you use a course book and you start combining it with other things, students can experience this as confusing. There will be a lot of resistance if you do not find a solution for this".

The teachers understand that it is difficult to make the module fit in with the curriculum, as one teacher claims:

> "It is the standard pitfall with things, you find an interesting context and you can relate the entire chemistry to that if you want. The question is how do you limit what you offer (…) you need to give the module a specific goal with a limited number of concepts behind it".

Two teachers express that they are bound to their fixed PTA, which leaves little room to mix up their curriculum. Another possible pitfall that teachers foresee is related to classroom management. Guiding and facilitating students while they work in groups of four in a class of 33 students can be challenging. It can be especially difficult to monitor the students' progress and their equal understanding of the topic. Furthermore, one of the teachers indicates the importance of a proper and attractive layout of the materials. This is often lacking in the existing context-based modules and is one of the reasons why the modules are not used at their school.

Most interviewed teachers believe that the 5E instructional model is feasible and not too difficult to implement. However, they express that it is always difficult to motivate students, whether it is in traditional or context-based teaching. Several teachers believe that the explore phase is not appropriate for every topic. Especially during difficult topics, students require more guidance and structure. Additionally, they express this phase should not take up too much time and the experiments that are included in the materials should be appropriate to the students' level. One teacher argues:

> **"**There are several experiments included in our course book that are meant to trigger students and to make them engaged in the topic, and then I'm thinking why on earth did they choose these experiments? A lot of thought should go into that (…) And they should work"

The interviewed teachers with a high level of innovation experience claim that in their experience you cannot give the students too much freedom, because they will develop misconceptions or fail to grasp the central concepts. One teacher claims:

> "Students are often not capable of uncovering the important concepts on their own"

The questionnaire demonstrated that teachers are less worried about students developing misconceptions (mean = 2.77).

During the Explain phase, the expert teachers anticipate that students may receive too much information at once. Therefore, teachers should organize fixed moments for plenary class explanations. During the Elaborate phase, some teachers suggest it could be difficult to find other contexts where the same relevant concepts can be applied.

Most expert teachers prefer to assess the students' knowledge and skills with a formal test during the Evaluation phase. The teachers from one of the schools with a high level of innovation experience use peer-assessment to let students assess each other. They claim that the judgment of their students often closely resembles their own judgments. The teachers with less innovation experience are more sceptical, because context-based assessment is more labour-intensive than an exam, for both teachers and students. Consequently, many teachers question whether it is feasible. One teacher suggests:

> "Doing presentations with 33 students, in groups of 3, that is 11 groups. Five minutes for each presentation and 5 minutes in between, that comes down to about three lessons."

Although these teachers do not believe in the feasibility of organizing presentations or an exhibition, they do use alternative forms of assessment in their 6VWO classes. For example, they instruct their students to write a letter to their peers about a certain analysis technique. Most of the teachers indicate that they would still use a formal exam in addition to an alternative method of assessment, because it is the best way to capture the newly gained knowledge and skills. Several teachers indicate that it might be useful to perform formative assessments throughout the module, to monitor the progress and to ensure that all students understand the concepts.

Teaching emphasis. In CBE, three teaching emphases can be distinguished. The FS and KDS teaching emphasis receive the most support of teachers. Very little teachers indicate that they prefer an STS emphasis. Three of the thirteen interviewed teachers, who have a low or moderate level of innovation experience, show a clear emphasis on fundamental science (FS). One teacher claims:

> "Modules are often based on a need-to-know principle, and because I am concept driven I will be quicker to give them the information".

One of the other three teachers with an FS emphasis argues:

> "The context should not be the directive, because that is not what is most important".

The other interviewed teachers feel it is also important that students understand how chemistry knowledge is developed, and how the chemistry concepts relate to the natural world. One of the teachers with a high innovation experience suggests:

> "These students should become much more flexible in their way of thinking about how chemistry is developed in such a context".

This demonstrates an emphasis on knowledge development in science (KDS). Still, they argue that their main objective is to demonstrate that all students understand the central concepts. None of the teachers show an emphasis on science, technology and society (STS). In Table 7 it can be seen that the questionnaire also showed that the most teachers support an emphasis on KDS (mean = 3.97). The STS emphasis received the least support (mean = 2.94).

CBE advocate. For curriculum reform, it is highly beneficial if schools are supportive of innovations. If not, teachers should be willing to act as representatives of CBE. Most of the teachers mention that their school is open to innovation, although they are not always sufficiently supported in doing so. Only the interviewed teachers from one of the schools with a low level of innovation experience claim their school is less open to educational reform and they are not really encouraged or facilitated to participate in innovations. One of the teachers from this school argues:

> "It is really difficult, because within this school there is a very high teacher turnover."

The teachers explain that this is the reason that their school is focused on innovations. Only one of the three teachers from this school would be willing to advocate for CBE, because she believes in the success of the approach. The other schools are all open to educational reform and have previously participated in an innovation project at least once. The questionnaire demonstrated that teachers are not always sufficiently supported by their school in innovations (mean = 2,96) nor are they always willing to advocate for an innovation themselves (mean = 2,51).

Table 7.

Combined qualitative and quantitative data for teachers

	Concept	**Qualitative data**	**Quantitative data**	
			Mean	SD
Knowledge		Teachers have considerable knowledge of the CBE – 5E pedagogy, but little experience with the 5E instructional model.	1.65	1.02
Skills	Context handling	Teachers are interested in teaching within the context of current scientific research.	4.03	.79
		Teachers are willing to spend time on getting familiar with the context.	3.84	.96
	Learning regulation	Teachers generally find it important that students have a shared responsibility of the learning process.	3.58	1.01
		Teachers question their ability to apply loose control strategies.	3.21	.94
		Teachers have a preference for plenary class instruction.	3.92	.81
	(re-)design of curriculum materials	Teachers feel competent to adjust curriculum materials.	3.98	.90
		Teachers are not willing to spend a lot of time on adjusting materials.	3.08	1.24

	5E instructional model	Teachers see no obstacles in engaging students in the topic.	3,21	.91
		Teachers believe it is difficult to determine when they should provide students with just-in-time information.	3.85	.75
		Teachers find it difficult to support students in making concepts transferable to other contexts.	3.60	.78
		Teachers find it difficult to perform context-based assessments.	2.52	1.10
Attitudes	Perceived relevance	Teachers are generally enthusiastic about CBE and are willing to use it in their own practice.	3.35	1.06
		Teachers are generally enthusiastic about the 5E instructional model and are willing to use it in their own practice.	2.88	1.06
		Most teachers find it important that students explore materials independently before receiving the explanation.	3.05	1.04
		Many teachers believe that students will understand the concepts better if they explore independently first.	3.61	1.01
		Most of the teachers find the elaboration phase relevant.	4.28	.69
		Many teachers are sceptical about context-based assessment, and not all teachers are willing to use it in their teaching practice.	2.98	1.16
	Value congruence	There is a significant overlap between the teachers' belief system and the new curriculum about what a 'good practice' is.	3.53	1.01
	Judgments about success	Most teachers think it is feasible to implement a CBE – 5E module.	3.34	.95
		Teachers worry about students developing misconceptions.	2.77	1.07
	Teaching emphasis	Most teachers demonstrate an FS emphasis.	3.76	.87
		Some teachers demonstrate an KDS emphasis.	3.98	.76
		Few teachers demonstrate an STS emphasis.	2.94	.90
	CBE advocate	Most teachers are supported by their school in chemistry curriculum reform.	2.96	1.09
		Most teachers are not willing to act as representatives for CBE within their school.	2.51	1.29

4.2 STUDENTS

4.2.1 Knowledge

Corresponding to the classification of the schools, the interviewed students from two schools have little experience with CBE and do not recognize the approach. The students from the schools that have moderate to high experience with innovative chemistry education have experience with the context-based approach. They can define the most important features of the approach, such as learning within a context and performing scientific investigations. They also understand the most important implications of this approach for their learning (e.g. high level of self-regulated learning). The questionnaire demonstrated that most of the students had little to no experience with context-based modules (mean = 2.34).

It was examined whether students' skills and attitudes were influenced by their experience with context-based curricula. This was only the case for their confidence regarding their ability to explain what they observed in an experiment. There was a statistically significant difference between groups as determined by one-way ANOVA ($F(4, 103) = 2.874$, $p = .031$). A Tukey post hoc test revealed that students who have no experience with CBE find it significantly more difficult to explain what they observed in an experiment ($2{,}38 \pm 1{,}09$, $p = 0.038$) than the students who had a lot of experience with CBE ($3{,}667 \pm 1{,}51$). However, their experience did not influence the other items.

4.2.2 Skills

Research skills. In CBE, students perform several laboratory investigations in the context of current scientific research, for which they require specific skills. Table 8 shows that most students feel confident that they can perform investigations and experiments, which the questionnaire substantiates (mean = 4.11). However, some of the interviewed students feel it might be difficult because there is still a lot of unknown information. These students claim that they are afraid to establish misconceptions if they do not receive adequate support from the teacher. One student claims:

> "I think it is really important that the teacher does help us, so that we do not start doing things wrong or go in the wrong direction. The teacher should correct us in time and just guide us".

Furthermore, most students feel that they can explain what they observed in an experiment, which is not clearly supported by the questionnaire (mean = 3.41). They also feel capable of drawing reasonable conclusions based on evidence, which is also supported by the questionnaire (mean = 3.81).

Self-regulated learning. CBE requires students to develop a sense of ownership and responsibility of their learning. In the experience of the expert teachers, students generally find their way through context-based modules. Although they essentially like these modules, they can struggle with the lack of structure. Especially weaker students find this challenging, as it is less clear what is expected of them. It takes the students more effort to understand the material, when compared to the course book, but the teachers consider this to be a positive thing. Table 8 shows that most students feel confident of their self-regulatory skills (mean = 4.06). Moreover, roughly half of the students from the group interviews agree that this level of independence and responsibility can be expected from a VWO-student. The interviewed students claim to believe that they will become more actively involved in their learning process when learning in a context-based setting.

The students from the schools with a high level of innovation experience are generally positive about working with context-based modules throughout the year. However, they express that the materials provide very little structure. Although they find their way through it, they express the lack of structure makes it difficult to prepare for the final examination. In general, they are very positive about the context-based materials and prefer it over traditional teaching methods. Several students from the other schools also express that the lack of structure is something that they would find challenging. Only one student indicates that this is a reason why she would not want to learn chemistry in a context-based setting. The questionnaire also demonstrated that students want to know what their teacher expects of them (mean = 4.10) and wish for sufficient structure in the materials (mean = 4,29). Similarly, many students express that they want their teacher to explain important concepts through plenary class instruction, which is supported by the questionnaire (mean = 4.10). The interviewed students also believe that working in research teams will help them to understand the material better, because they can learn from each other.

Engage. Most students expect that an authentic research context will help them to become engaged in the topic, because they are enthusiastic to find out more about the scientific research. The questionnaire shows that students are indecisive on this subject (mean = 3.21).

Explore. Approximately half of the students indicate to find it difficult and possibly confusing to perform experiments and investigations, when it is not yet clear what information they are looking for. The other half of the students see this as a positive challenge, which will make them look for information more actively. One of the students suggests:

> "I like it better this way, because otherwise you are stuck to the theory to explain things. If you observe something and you start to think, 'can I find an explanation for this', you will think more from your own knowledge base.

The questionnaire shows slightly more support for the latter opinion, considering it as a positive challenge (mean = 3.55), although the difference between the mean scores is not large (mean = 3.20). When asked how they would feel if their investigations in the explore phase lead to incorrect results, one student claims:

> "I think that would be a problem. If you do not know what results should come out of the experiment, you do not know if you are doing it right".

Explain. Many students are afraid of establishing misconceptions, after exploring independently. If they are asked to generate their own explanations and find out they are wrong, they believe that these misconceptions are difficult to forget. They also believe that giving central explanations is the most efficient approach, especially in terms of time. The other students believe that it is easier to understand concepts when they can define them in their own words, or in the words of their peers, rather than when their teacher explains it. The questionnaire does not clearly substantiate this (mean = 2.57).

Elaborate. The students from the group interviews expect the elaboration phase to be a difficult step, because of their experience with exam questions that are often based on an unfamiliar context. One of the students with a high level of innovation experience argues:

> "I find that really challenging, because it is really something different. Also, you get very little guidance here, which makes sense, but you really have to dig deep with your group and that can be difficult."

Another student suggests:

> "It has to do with application, and you need to understand the material well. If you managed well in the previous phases, you should be fine."

Several other students agree that they can only be successful in the Elaborate phase, if they understood the material of the preceding phases sufficiently.

Evaluate. The students claim that formal testing is necessary to demonstrate their knowledge and/or skills. They do not believe that they can sufficiently demonstrate this by alternative forms of testing. One student suggests:

> "I feel like you can really study for a formal test, which makes you feel ready to begin the new chapter, because you are sure that you understand everything."

Other students are more positive about alternative (context-based) assessment, because they perceive it is easier, more fun, and less stressful. Moreover, some students believe that context-based assessment promotes the development of other relevant skills. One student argues:

> "I think that you will need to do a lot of research on the topic if you need to make a presentation or report, which will make you understand it on a deeper level then when you just study for a test."

The questionnaire does not show a clear preference for formal testing (mean = 3.16). Most interviewed students are open to a different type of assessment if they will still be formally tested on their understanding of the concepts as well.

4.2.3 Attitudes

Motivation. CBE has demonstrated to increase students' motivation and enjoyment of science. Most interviewed students are enthusiastic about the proposed pedagogical framework, and indicate they would like to learn by this approach. The questionnaire shows that students are indecisive on this matter (mean = 3.39). The interviewed students that have experienced a context-based course claim that this approach increased their motivation and enjoyment of chemistry learning. The students that have not yet learned in a context-based setting expect the same result and they would like the variation.

Most of the students express that they enjoy chemistry more when they can learn it through practical work, with a lot of variety and the freedom to make their own choices. Table 8 shows that although the questionnaire does not clearly support the statement that CBE in general increases their motivation (mean = 3.21), they do find other aspects motivating, such as practical work (mean = 4.10), a high level of self-regulation (mean = 3.58), and learning in the context of current scientific research (mean = 3.87).

Almost all students are enthusiastic about collaborative learning. Only one student expresses to prefer working alone, and a few others indicate that they appreciate alternation. The questionnaire shows that students were undecided in their preference (mean = 3.12). Some students indicate that they expect certain students to attempt to free-ride if they work in research teams, although most of them believe that the materials can be designed in such a way that this is less probable. Several interviewed students suggest that the CBE – 5E pedagogy will help them to get better learning outcomes. However, the questionnaire does not clearly substantiate this (mean = 3.19). The students from one of the schools with a high level of innovation experience believe that their above average grades are the result of learning consistently with a context-based approach.

One of the students argues:

> "I think it will stay in your long-term memory better. Otherwise you hear it and forget it after the exam. Also, because it appeals to you more, you remember it better".

One of the reasons for this expected improvement is that the students are closely involved in the topic for a longer period of time. Also, they believe it is easier to recollect the concepts afterwards, if it is linked to an authentic context in their memory. Finally, most students claim that they would not like to be assessed by context-based evaluation methods. Table 8 shows that the questionnaire supported this (mean = 2.67).

Value. In the perception of most students, CBE is a valuable learning approach. The expert teachers claim that in their experience, the attitude of students toward context-based materials is twofold. Some students do not see the added value of the module and wonder why they cannot simply learn by the course book. Other students like the variety and find it interesting to learn in the context of current research. The interviewed students all agree that the context-based approach will make the chemistry content more meaningful, because it is directly related to an authentic context. The questionnaire supports this statement (mean = 4.04). One of the students mentions:

> "You will know what you are doing it for, and what you can use it for."

Another student suggests:

> "I think you will look at the subject matter differently. I think chemistry is very difficult, and this way you can think about it more logically. Maybe that will make it easier to understand."

This demonstrates that the students see the added value of the approach. The students with a high level of innovation experience claim that they feel this approach is a good preparation for the final exams and for university. Only one student expresses a negative attitude towards the context-based approach, mostly because the lack of structure and direct supervision.

The students are generally positive about the sequencing of the phases in the 5E instructional model. The students express that they believe that learning by the 5E instructional model will help them to see how concepts are related to each other, and to relate the new concepts to their prior knowledge. The questionnaire confirms these findings (mean = 3.83). They claim that it is easier to see the relation amongst concepts and to draw conclusions from evidence. The students from one of the schools with a high level of innovation experience indicate that during the Engage phase they often are asked to make a word web about the topic to identify their prior knowledge. Four of the students find this very useful, although one student claims she finds it unnecessary. Most students recognize the value of exploring materials prior to the explanation. Most of the students think the Elaborate phase is very important, because this will help them to get a deeper understanding of the concepts. The questionnaire confirms that students believe the elaboration phase is educational (mean = 3.94). The students believe this phase will help them to make the concepts more transferable. Only one student is less positive and argues:

> "Basically, it is just another form of repetition, so if you already understand the concept it can be really annoying to keep repeating it".

The interviewed students all see the relevance of the evaluation phase. One student suggests:

> "We did a project once, but there was no real evaluation which left us questioning why we did the project at all. The assessment should be part of the module, otherwise people will see it as a joke."

However, not all students are enthusiastic about context-based assessments, which is supported by the questionnaire (mean = 2.67). Some of the interviewed students that were positive about context-based assessment argued that it is good to be tested on other skills as well, such as presentation and research skills.

Table 8.

Combined qualitative and quantitative data for students

	Concept	**Qualitative data**	**Quantitative data**	
			Mean	SD
Knowledge		Not all students have *experience* with the CBE – 5E pedagogy. Only the students with context-based learning experiences recognize the CBE – 5E pedagogy and can define its underlying principles.	2.34	1.22
Skills	Research skills	Students are relatively confident of their ability to perform scientific investigations and experiments.	4.11	.77
		Most students feel that they can explain what they observed in an experiment.	3.41	1.05
		Students feel they can draw reasonable conclusions based on evidence.	3.81	.79
	Self-regulated learning	Students feel they are capable of handling a high level of self-regulated learning (i.e. working independent from the teacher, making choices in the learning process).	4.06	.84

		Students think it is important to know what their teacher expects from them.	4.10	.83
		Students think it is important that there is *sufficient structure* in the materials to guide their inquiry.	4.29	.80
		Students find it important that their teacher explains important concepts through *plenary class instruction*.	4.10	.913
	5E instructional model	Most students think they will become easily *engaged* in the topic, because of the authentic context.	3.21	1.09
		Approximately half of the students find it *exciting* to explore concepts through experimenting, before they know details about the topic.	3.55	1.15
		Approximately half of the students find it *confusing* to explore concepts through experimenting, before they know details about the topic.	3.20	1.11
		Some students argue that they understand concepts better when their peers explain them, instead of their teacher.	2.57	1.03
		Most students think they best demonstrate their knowledge and/or skills through traditional testing	3,16	1.20
Attitudes	Motivation	Most students are enthusiastic about learning with the CBE – 5E pedagogy.	3.39	1.16
		Most students believe *the CBE – 5E pedagogy* will increase their motivation and enjoyment of chemistry.	3.21	1.13
		Many students enjoy working on *practical assignments*, such as experiments.	4.10	.91
		Some students express that the high level of *self-regulation* will increase their motivation.	3.58	0.92
		The students find the *scientific research context* interesting and motivating.	3.87	.86
		Most students prefer a combination of group work and individual work. Some students prefer working *alone*.	3.12	1.19
		Some students believe that the CBE – 5E pedagogy will improve their *learning outcomes* (i.e. grades).	3.19	1.02
		Not all students are enthusiastic about context-based *assessments*.	2.67	1.03
	Value	Students believe that an authentic context will make the chemistry content more *meaningful*.	4.04	.94
		Students believe the 5E instructional model will help them to see how concepts and contexts are related.	3.83	.90
		Most students find the *Elaborate phase* valuable and educative.	3.94	.87
		Many students argue that they learn a lot from peer-to-peer discussions.	3.87	.95

5 Conclusion and Discussion

The research questions will be answered by summarizing the knowledge, skills, and attitudes of teachers and students towards the proposed pedagogical framework that have been demonstrated by this research. The guidelines in Table 9 (p. 48) show how curriculum designers can attend to the knowledge, skills, and attitudes of teachers and students and promote the successful implementation of the intended curriculum change. Next, a reflection on the findings and research methods is presented. Based on the data that was collected in this study, recommendations are presented for future research and practice. Finally, the concluding remarks are presented.

5.1 Conclusion

This research attended to the following question: *How can curriculum materials help foster the knowledge, skills and attitudes of teachers and students towards teaching and learning with the 5E model in a context-based chemistry curriculum inspired by current scientific research?* To answer the main research question, the following sub questions were first answered:

SQ 1. What are the knowledge, skills and attitudes of teachers towards the pedagogical framework used in the proposed chemistry curriculum?

SQ 2. What are the knowledge, skills and attitudes of students towards the pedagogical framework used in the proposed chemistry curriculum?

The sub questions have been answered based on the combined findings of the focus group, group interviews and questionnaire.

5.1.1 Knowledge, skills and attitudes of teachers

It can be said that teachers have sufficient knowledge of the CBE – 5E pedagogy. Most teachers can identify the most important features of CBE, such as the ‘need to know’ principle. Teachers generally recognize the sequencing of activities in the 5E instructional model, even though they have not used it in practice yet. Teachers’ experience with innovative chemistry curricula only had a significant influence on teachers’ confidence regarding the adjustment of curriculum materials, but not on the other skills and attitudes. Thus, it can be argued that experience is not enough to be successful in implementing a curriculum with the CBE – 5E pedagogy.

Teachers are generally positive about their context-based teaching skills, which are: context handling, learning regulation, and (re-)design of curriculum materials. Teachers are generally willing to spend extra time on getting familiar with the scientific research context that is used in the materials and they feel competent enough to do so. Many teachers struggle with the unorthodox teaching methods of CBE. The findings show that not all teachers are convinced of their ability to apply loose control strategies. Not all teachers are willing to spend time on adjusting curriculum materials to fit their practice. However, they are more confident about their ability to do so.

Teachers are overall confident of their ability to teach with the 5E instructional model, although they are concerned that students could develop misconceptions and suggest it could be challenging to ensure that all students reach the same level of understanding. Most teachers are confident of their ability to assess when they should provide just-in-time information. The teachers consider the elaboration phase the most difficult phase to implement, because it requires them to make connections between concepts and contexts visible for students. Finally, most teachers prefer formal testing over context-based assessments, because it is easier to assess students' skills and attitudes through traditional formal testing and it is easier to organize.

Generally, teachers have a positive attitude towards CBE. All teachers agree that the CBE and the 5E instructional model are valuable and relevant teaching methods. However, several teachers argue that the phases in the 5E instructional model should be deliberately used because it adds value to the learning process. On average, there is a value congruence between the context-based approach and teachers' personal beliefs about what a good practice is. The teachers express several judgments about the success of the new curriculum. Some teachers feel there is not enough time to implement a context-based module or their classes are too big. Many teachers suggest that it should be made clear how the new curriculum fits into the existing curriculum. The teachers believe that teaching by the 5E instructional model is feasible, although they believe some students need more structure and guidance than the model offers. They do argue that the Explain phase will only be successful if they can give plenary class explanations of the important concepts. They are also sceptical about the success of context-based assessment. Most of the teachers support an FS or KDS emphasis. Finally, few teachers indicate that they are willing to act as a representative for CBE within their school, if their school is less supportive of innovations.

5.1.2 Knowledge, skills, and attitudes of students

Not many students recognize the proposed pedagogical framework. Only the students who have learned with context-based modules before do, and are able to define its core features. Students' experience with context-based curricula only influenced their confidence regarding the ability to explain what they observed during an experiment, but not the other skills and attitudes. Accordingly, experience with CBE does not necessarily lead to successful learning.

Most of the students are convinced that they can perform investigations and experiments, and draw reasonable conclusions based on evidence. However, some students fear that without sufficient guidance they might establish misconceptions. Most students are confident about the level of self-regulated learning in CBE, although many students find it important to know what their teacher expects from them. They also stress the importance of a sufficient structure in the materials. Approximately half of the students are confident of their ability to perform investigations and experiments when it is not yet clear what information they are looking for and say they find it exciting. The other half of the students claim they find it difficult and possibly confusing. Most students agree that it is important that the teacher gives plenary class explanations regularly. The students believe that the elaboration phase will be the most difficult. Finally, they do not believe that they can demonstrate their knowledge and/or skills by context-based assessment.

Most students are enthusiastic about the proposed pedagogical framework. Although most students do not believe the CBE – 5E pedagogy will increase their motivation and enjoyment of chemistry in general, they do believe that the scientific research context, the high level of self-regulation and working in research teams on practical assignments will increase their motivation. Not all students believe that the CBE – 5E pedagogy will improve their learning outcomes. Overall, the students see the value of CBE, as well as the 5E instructional model. The students also believe that CBE makes the chemistry content more meaningful, and that the sequencing of the 5E instructional model will help them to see how concepts are related to each other and to their prior knowledge.

5.1.3 Curriculum materials

To answer the main research question, the findings from the two sub questions are revisited in light of the literature on chemistry curriculum materials that support teachers in curriculum reform. The literature was used to prompt specific design guidelines for a CBE – 5E curriculum based on the data from the present study. The findings of this study give insight into the current situation of teachers and students regarding their knowledge, skills, and attitudes toward the CBE – 5E pedagogy. The findings show that teachers and students possess many of the desirable knowledge, skills, and attitudes, as described by the literature. However, the findings also show that there are some aspects that they are less confident about, or have a slightly less than desirable attitude towards. These are important aspects that should receive special attention in the curriculum materials. The literature on curriculum design brings forth several important themes that designers should pay attention to. The data of the present study shows us which issues are especially important for teachers and students. Drawing on both sources, the design guidelines for context-based chemistry curricula describes the key issues that curriculum designers should attend to, to design materials that pay close attention to the enactment process. The key issues are:

- Support for teaching methodology
- Support for assessment
- Practicality
- Support for science topics
- Support for scientific inquiry
- Support for subject matter knowledge

As a result, the guidelines show specifically how CBE – 5E curricula can be designed that foster the knowledge, skills, and attitudes of teachers and students. By using these guidelines to make informed decisions, curriculum materials can be designed that promote the successful implementation of the intended curriculum reform, by paying close attention to the curriculum enactment processes. Table 9 describes what curriculum materials can and should provide teachers and students in response to the abovementioned key issues, the corresponding design guidelines, and an example application. A summarized version of these guidelines is included in Appendix C.

Table 9.

Design guidelines informed by teachers' and students' knowledge, skills, and attitudes

Key issues	Guidelines	Example
Support for Teaching Methodology		
Facilitating Learning Why: Teachers are less confident of their ability to determine when just-in-time information should be provided, and question their ability to apply loose control strategies. Teachers are worried that cannot monitor students' growing understanding of concepts.	✓ Include important just-in-time information ✓ Support teachers in applying loose control strategies and describe why these strategies are pedagogically appropriate ✓ Support teachers in monitoring students' progress (e.g. glossary, log book)	*JIT: Before students start working on experiment A, make sure to explain principle X. This will help students understand the experiment better, and will steer their observations towards this principle, making the experiment more meaningful.*
Lesson preparation Why: Curriculum materials should support teachers and students in setting clear expectations by providing a clear outline of the lessons. Students are confident of their self-regulatory skills, but stress the importance of sufficient guidance and clear expectations.	✓ The materials should provide a description of the lesson aims and how activities contribute to these aims. ✓ The materials should provide students with sufficient structure; they should know what is expected of them during each phase of the 5E instructional model.	*Explore: You will perform laboratory investigations with your group. You should stay open-minded and think freely, while you explore possibilities and consider alternative solutions.*
Support for Checking Learning Effects		
Context-based Assessment Why: Teachers and students sometimes fail to see the relevance of context-based assessment. Different teachers prefer different assessment methods.	✓ Describe the rationale behind context-based assessment methods ✓ Provide teachers with various options for context-based assessment methods	*Context-based testing assesses and promotes students' higher-order thinking skills (e.g. problem solving and inquiry skills). Also, learning outcomes may improve if the assessment method is aligned with the teaching methods.*

Transfer of concepts <u>Why</u>: Teachers and students consider the elaboration phase as the most difficult to implement, because of the transfer of concepts.	✓ Support teachers and students in making concepts transferable ✓ Include a formative test before the elaborate phase, to assess students' (growing) understanding of a concept	*Before starting the elaborate phase, ask students to explain phenomenon C. If they can explain this by using principles X and Y, they understand how these principles are applied within this context.*
	Practicality	
Congruence <u>Why</u>: Teachers argue that experiments sometimes neglect to pay attention to the practical implementation in classrooms.	✓ Experiments should include a rationale, possible pitfalls and should work properly. The materials should describe how the experiments can be used in practice ✓ Include an overview of required materials and equipment	*Experiment A can be used to illustrate principle X. You can use it as a class demonstration to focus students' attention towards this specific principle. When students see the effects of experiment A, they will understand that (…). While performing the experiment, make sure you (…), otherwise it will not give the correct results.*
Supporting Curriculum Coherence <u>Why</u>: Many teachers argue that coherence with their existing course book is imperative.	✓ It should be made clear how the new curriculum fits into the existing curriculum based on the chemistry topics that are covered.	*This module will cover concept: (...). This concept is explained in book chapter(s) 2.4, 2,5 and 4.1 in course book A, and 2.3 and 2.4 in course book B (etc.).*
Supporting Curriculum (re-)design <u>Why</u>: Experienced teachers are confident of their ability to adjust the materials based on their teaching practice and their learners' needs, but inexperienced teachers are less confident. The materials should be both adaptable and meaningful.	✓ Allow multiple points of access ✓ Emphasize key building blocks rather than procedural steps ✓ Explain the rationale behind instructional resources, but allow for use in different contexts	*For each phase of the 5E instructional model, we made an outline of the corresponding learning activities. You can choose to implement these lessons as they are, or move between the phases more flexibly based on your students' level, or the amount of available time.*
	Support for Science Topics	
Topic-Specific Scientific Phenomena Curriculum materials should explain why the particular scientific research is appropriate as a context. Teachers and students argue that the scientific research context can easily become too complicated for students.	✓ Describe a rationale behind the chosen context ✓ The scientific research context should be written on a student-level	*The language should not be too formal, connecting to the level of understanding of students.*

Students' Ideas About Science <u>Why</u>: Curriculum materials should identify the importance of students' ideas. Both students and teachers are worried about misconceptions in CBE.	✓ Identify the importance of assessing prior knowledge ✓ Include common misconceptions and ways to deal with these (e.g. challenge misconceptions in the appropriate way)	*For this concept, it is common that students believe X when it is in fact Y. To deal with this misconception, show the student that X does not hold up in a different situation. Then, explain that Y is more plausible, because it does solve the problem here.*
	Support for Scientific Inquiry	
Engaging Students in Questions <u>Why</u>: Driving questions may support teachers in applying loose control strategies and encourage students to look for answers themselves.	✓ Provide teachers with driving questions to elicit student responses in each phase of the 5E instructional model. Describe why questions are pedagogically and scientifically appropriate	*(Explore) Instead of giving students the right answer, ask them what could explain the results from their experiment. You can ask them how they think it is possible that (...), which should steer them in the direction of principle X.*
Engaging Students with Collecting and Analysing Data <u>Why</u>: Each phase of the 5E instructional model contributes to students' scientific inquiry, but not all teachers see their relevance. A rationale should be provided for why each phase contributes to students' learning progress.	✓ The 5E instructional model should guide students' inquiry ✓ Include rationales for each phase ✓ Provide approaches to guide students through the process of collecting, compiling, and understanding data and observations.	*During the elaborate phase, students' conceptual understanding and skills are extended by applying concepts in new (but similar) contexts. The students develop a deeper and broader understanding, more information, and adequate skills.*
Engaging Students in Making Explanations Based on Evidence <u>Why</u>: Teachers often prefer giving plenary class explanations. Other strategies may be more beneficial for CBE.	✓ Include recommendations for how teachers can support students in generating explanations in various ways, as well as the rationale behind these recommendations.	*Ask students to write down their explanation of phenomenon B. After that, let the students discuss in groups. Through these discussions, students will think critically about alternative explanations.*
Promoting Scientific Communication <u>Why</u>: Teachers should promote students' productive scientific communication	✓ Students could keep a logbook or lab report where they write about their process (what, how and why they did things)	*During experiment A, what did you do, why did you do this, and how did you divide the tasks within your group: _____*
	Support for subject matter knowledge	
Development of Subject Matter Knowledge <u>Why</u>: Teachers are confident of their ability to familiarize themselves with contexts and concepts, but do not want to spend too much time on this.	✓ Provide teachers with elaborate information about the (scientific research) context ✓ Support teachers with elaborate subject matter information	*In this module, the scientific research of (...) is used as a context. This research is currently being conducted at the University of Twente in Enschede, and focuses on (...). To learn more about this research, go to [website].*

5.2 Reflection on the findings

The current study contributes to the existing research by providing specific guidelines for designing curriculum materials with a CBE - 5E pedagogy that can be used by designers to create materials that promote a successful implementation. By examining the existing knowledge, skills, and attitudes of teachers and students, curriculum materials can be designed that pay close attention to the curriculum enactment process. The findings of this research demonstrate the current knowledge, skills, and attitudes of teachers and students. The conceptualization in chapter 2 demonstrates the desired situation, which can help to identify possible gaps that need to be bridged. The knowledge, skills and attitudes of teachers and students can help to understand how they perceive the context-based materials, and what they might need to successfully teach and learn by this approach.

The present study was performed in the context of the Impuls project. The guidelines that are presented in this study can help their design team to ensure a successful implementation of their materials. The designers can accommodate their materials to the needs and wishes of teachers and students that have been identified in this study. In the long term, other context-based curriculum designers can also benefit from this. The findings of the present study will be examined in a broader perspective, by making connections to previous studies.

5.2.1 Teachers' knowledge, skills, and attitudes

The findings from the TDT focus group, group interviews and questionnaires show that most teachers have experience with the context-based approach and recognize its implications for their teaching practice. However, their level of experience has little impact on their self-perceived skills or attitudes, with the exception of their confidence to adjust curriculum materials. This illustrates the importance of good support for teachers in implementing new curriculum materials.

Overall, the teachers are enthusiastic about teaching in the context of current scientific research, and are willing to spend time to familiarize themselves with the context. Considering the teachers have chosen chemistry as their teaching subject, they have a fascination and interest in this topic. In CBE, teachers should discuss issues with their students that go beyond the subject matter (e.g. its relation to real-world phenomena). They should also be able to respond to unanticipated questions from students (Davis & Krajcik, 2005; Gilbert, 2006). The teachers question their ability to apply loose control strategies. Avargil et al. (2012) also found that teachers struggled with adopting the unorthodox teaching methods of CBE. It is possible that teachers will grow to be more confident of these unorthodox teaching methods as they gain more experience with CBE, but that is just speculation. The teachers who often work with chemistry modules as a substitute for the course book feel more competent to adjust materials. All teachers generally recognize the need for redesigning the context-based materials as implicated by De Putter-Smits et al. (2012). This corresponds to the findings of Stolk et al. (2011), who reported that teachers were confident and motivated to adapt curriculum materials. The teachers indicate that formative assessment or regular monitoring may be necessary to keep track of students' progress, because teachers have little control over the learning process. They argue this is important to ensure that all students reach the same level of understanding. Although many teachers mentioned this in the interviews, it should be noted that even in traditional education the same level of understanding is never reached. Students' test results show a lot of variety in any type of education. Previous studies have indicated that teachers find it difficult to create a "need to know setting", because it is not always clear when information or instruction is needed based on the just-in-time principle (Kester et al., 2001; Schwartz, 2006; Stolk et al., 2011). The interviewed students in the present study agree that it can be difficult to determine when instruction or information is needed, although the questionnaire did not confirm this. However, Stolk et al. (2011) reported that in practice, teachers were somewhat able to solve the 'need to know' issue. One of their approaches involved carefully guiding student discussions towards the chemistry concepts.

Although the overall attitude of the teachers toward the pedagogical framework is positive and teachers recognize the relevance of the curriculum, several concerns are expressed by the teachers regarding the successful implementation of a context-based module. Many teachers who decided against the use of context-based modules in the past, say that the main reason for this was that they had to spend too much time on figuring out which topics were covered by the module and how it could replace parts of their course book. This 'puzzle' was often too difficult for teachers to solve, making the module very unattractive. Furthermore, teachers suggest that the experiments that are included in the materials should be appropriate for the level of the students and they should work in practice. Parchmann et al. (2006) also indicated that the available equipment of schools should be considered when designing context-based curricula that include laboratory activities. Several teachers are concerned about the classroom management. Guiding students while they work in groups on research activities, when classes can be as large as 33 students, is considered as quite a challenge. This corresponds to the findings of Schwartz (2006), who suggested that innovative curricula appear to have more chance of success in small classes. In line with the findings of previous studies (Bennett et al., 2005; Nentwig, Parchmann, Demuth, Graesel, & Ralle, 2002; Sutman & Bruce, 1992), teachers question whether students are ready for the level of responsibility that is required in CBE, especially the low-achieving students. However, Nentwig et al. (2002) suggested that their context-based materials had the most impact on low-achieving students.

Overall, teachers believe in the success of the 5E instructional model. They expect the elaboration phase to be the most difficult to implement, because they need to make connections between concepts and contexts visible for students. In line with the findings of Vignouli et al. (2002), the teachers expect it to be challenging to make the concepts transferable to new situations. Furthermore, the teachers were sceptical about context-based assessment. They indicate two reasons for why they prefer traditional formal testing: it is easier to organize and it is easier to assess students' knowledge and/or skills. This corresponds to the findings of previous studies (Avargil et al., 2012; Bennett et al., 2005). However, Pilot and Bulte (2006) stress the importance of appropriate assessment. Context-based testing should not 'de-contextualize' knowledge, but should rather focus on rewarding context-based competencies. It is important that curriculum materials explain the rationale behind context-based assessment, to improve teachers' attitude toward this activity. Furthermore, different teachers prefer different assessment methods. The present study shows that some teachers were sceptical about assessing students based on presentations, although they were positive about other types of context-based assessments. Parchmann et al. (2006) also reported that teachers wanted to be free in making their own choices.

The majority of the interviewed teachers demonstrate an FS or KDS emphasis, which corresponds to findings of previous studies (Van Driel et al., 2005). It has been argued that an emphasis on KDS or STS is the most effective for context-based teaching. Avargil et al. (2012) observed that teachers with an FS emphasis made little effort to relate concepts to everyday life. In the present study, the interviewed teachers that demonstrated an FS emphasis suggest that they do attempt to make these connections to make the concepts more meaningful for students. Furthermore, the questionnaire demonstrated that not all teachers have a clear preference for one single emphasis. Many teachers responded positively to both an FS and an KDS emphasis. This corresponds to the findings of Van Driel et al. (2005), who found that some teachers even supported all three emphases. They argued that this implies that 'within teachers' curriculum beliefs, there is room for various perspectives' (p. 119). Thus, although it can be said that many teachers in this study predominantly demonstrate an FS emphasis, most of these teachers understand that this is not where their teaching job ends.

The teachers do not explicitly express to be willing to act as a representative of CBE. However, it can be argued that it is only necessary for teachers to act as a representative if they want to implement CBE on a school-wide level. If they want to adopt the approach in their own classroom, they only need the support of their school board to use new curriculum materials. Thus, the skill that is related to school innovation is only important in particular situations. Nonetheless, teachers who have a negative attitude towards CBE cannot be expected to act as representatives.

5.2.2 Students' knowledge, skills, and attitudes

Overall, the knowledge of the students regarding the pedagogical framework corresponds to their level of innovation experience. The students who have previously engaged in several context-based modules are aware of the underlying principles of CBE and its implications for their role as a student and the way they learn. Experience with CBE has shown to have little influence on the confidence of students regarding their skills and their attitudes. Therefore, it can be argued that students need to be supported in the materials regardless of their experience, for example by setting clear expectations regarding their role as a student and their learning goals.

The students are generally confident about their context-based skills. Most students are confident of their research and self-regulatory skills. This contradicts the expectations of teachers, who have less confidence in the skills of their students on these aspects. It is not uncommon for respondents to overestimate themselves in self-report instruments, which could be the case here as well. Moreover, the findings show that students wish for a balance between the freedom to explore and adequate support and guidance. Some students believe that it will be confusing to explore materials before they receive the explanation and fear this will lead to misconceptions. However, as it has been argued before, the freedom to explore does not necessarily lead to misconceptions.

The students are overall confident about their skills and competencies. However, a significant percentage of the respondents has no experience with the approach. The group interviews show that students who have no experience with context-based learning generally express the same perspectives. It can be argued that their statements are based on expectations. For example, they suggest they would not mind the level of responsibility that is required of them. However, there is a possibility that they would feel different after experiencing context-based learning. The students expect their self-confidence to increase when they perform independent investigations, which corresponds to findings of previous studies. However, Osborne and Collins (2001) claim that when students produce incorrect results their self-confidence will not be harmed. The students from the present study fear that could be confusing, especially because it is not yet clear what results they are looking for.

In line with previous studies, the students expect that the chemistry content will become more meaningful if the concepts are directly related to an authentic context (Bennett, Hogarth, & Lubben, 2003; Osborne & Collins, 2001; Ultay & Calik, 2012), their motivation and enjoyment of chemistry learning will increase and their learning outcomes will improve (Demircioglu et al., 2009; Osborne & Collins, 2001; Ultay & Calik, 2012). The students mention several reasons for this, such as doing practical work, working in groups, variation, and being able to make choices in the learning process. However, the questionnaire shows that not all students believe that the overall CBE – 5E pedagogy will improve their learning outcomes. It is difficult to compare students' learning outcomes in CBE and traditional education, because of the different types of examination. This makes it impossible to make an objective comparison. However, previous studies have indicated that the best learning outcomes are achieved when there is a close link between the design of the assessment items, and the teaching approach that is used in the course (Barber, 2001; Bennett & Lubben, 2006) This tells us that it is beneficial to end a context-based module with a fitting assessment.

Overall, students recognize the value of the 5E instructional model. The theoretical value of the model is that it helps to sequence the lessons and the understanding of a concept over time (Bybee & Landes, 1990). The results from the group interviews show this is how students experience it in practice as well. They feel that the model could help them to build up the knowledge. First, their prior knowledge gets activated, after which they perform experiments to explore the concepts. By receiving the explanation after this experimentation, they can connect the new knowledge to their observations, which makes it more meaningful and concrete.

5.3 Methodological reflection and recommendations for future research

Triangulation of quantitative and qualitative research methods has shown to be valuable, because it provides more thorough insights. The qualitative data provided in-depth insights into the perspectives of teachers and students, whereas the quantitative data provided the opportunity to generalize and substantiate the previous findings.

Much like any other study, the applied research methods have their limitations. The students who participated in the group interviews were selected by the teacher, often based on a voluntary basis. For example, one of the teachers instructed the students who were already finished with the assignment and felt they understood the subject matter sufficiently to take part in the interview. Therefore, it is possible that the students who participated were high-achieving students. Furthermore, the interviewed students were mostly female. This was probably a coincidence, because more female students volunteered to participate in the interviews. It could be noted that the teachers and students participated voluntarily in the study, except for the students who filled out the questionnaire. These students were instructed to do so by their teacher during one of their chemistry lessons. It is possible that these students were less willing to participate, which could have influenced the results of the questionnaire. Additionally, most of the students who filled out the questionnaire were 5th year VWO students. This was a coincidence, since the teachers were asked to let students from the 4th or 5th year fill out the questionnaire. The study was designed to include students from 4 and 5 VWO, because these students are also the main target audience for context-based learning. The Impuls design team also wants to design materials for students of these grades. It is possible that students from 4 VWO have different perceptions that are not well represented in the outcomes of the questionnaire. However, the current findings of the interviews and questionnaire showed minor differences between the opinions of 4 and 5 VWO students. Therefore, it is expected that the outcomes would not be significantly different if more 4 VWO students had participated in the questionnaire.

Another issue related to the student group interviews, is that participants of this age are sensitive to socially desirable behaviour. Although the questions were phrased as neutral as possible to avoid bias, and follow-up questions were asked, this is still a factor to consider. The students were generally very positive about the context-based approach, but they could have been giving socially desirable answers. Additionally, the students who had no experience with CBE sometimes struggled to understand the essence of the approach. It was a challenge to explain the important features of CBE in such a short time. Therefore, it is possible that some students did not fully understand how CBE and their role and responsibilities as students differed from traditional education. This issue also relates to the questionnaire, as several students commented that they found it difficult to understand the explanation of the context-based approach. This is important to keep in mind while interpreting the findings if this study.

Although the research methods were useful in providing insights into the perspectives of teachers and students, it is difficult to assess whether the findings match the reality. The data collection consisted of a self-report on skills, which is possibly not the most objective measurement method. The reported perspectives on skills could better be viewed as self-efficacy. For example, students thought they had sufficient research skills, although their teachers were less confident. This illustrates that a self-report on skills may not produce the most objective results. The actual skills of teachers and students could be measured more objectively by observing the implementation of a context-based module in practice. Moreover, this made it difficult to discriminate between skills and self-efficacy as an attitude. It is possible that there is an overlap between these two concepts, because their definitions in this study are quite similar. Future research could measure the knowledge skills and attitudes of teachers and students after the implementation of context-based modules, for example through classroom observations. This would result in a more objective measurement of skills. Additionally, the instruments from this study could be used to measure the perceptions of teachers and students after the implementation, to see whether the perceptions have changed over time.

Finally, it should be noted that the questionnaire was designed specifically for this study. The questionnaire was designed to measure whether the most important and/or striking findings of the focus group and group interviews were substantiated by a larger sample. Therefore, the questionnaire may not include all concepts that were identified in the beginning of the study, but rather the concepts that were the most relevant for this particular sample. If researchers would want to use the instrument in future studies, it is likely that they would need to adapt the instrument according to their research goals. The questionnaire could be further investigated and improved by experts, so that it can be used in future research (e.g. Driessen & Meinema, 2003; Bulte et al., 2006; Pilot & Bulte, 2006; Westbroek, 2005). Additionally, the design guidelines could be evaluated by the same experts.

5.3.1 Remaining challenges

The data of the present study has identified several key issues that should receive special attention from curriculum designers, based on the knowledge, skills, and attitudes of teachers and students. The design guidelines show how curriculum materials can respond to these issues. However, there are two aspects that remain a challenge, because it is not yet clear if and how curriculum materials can resolve these issues. First, most of the teachers in this study express an FS or KDS emphasis. The FS emphasis is considered to be the least preferred in CBE, because teachers who support an FS emphasis are more likely to use teacher-centred approaches (Overman, Vermunt, Meijer, Bulte, & Brekelmans, 2014). More research is needed to examine what curriculum materials can do to promote teachers who support an FS emphasis in adopting a KDS or STS emphasis. Finally, not many teachers are willing to advocate for CBE within their school, if their school is less supportive of curriculum innovation. Darling-Hammond and McLaughlin (2011) argue that teachers need a supportive learning community to share experiences, expertise, dilemmas and feelings. However, it is unclear if curriculum materials can play a role in this matter, and if so how. Like Overman et al (2014) suggested, future research should address how teachers can be supported in their professionalization within their schools, and moreover, how curriculum materials can contribute.

5.4 Recommendations for practice

Based on the findings of the present study, the following recommendations can be made for curriculum designers. It is important that curriculum designers recognize that the CBE – 5E pedagogy requires significant changes in teachers' and students' behaviour. They should appreciate the complexity of implementing a new curriculum. Moreover, they should recognize that curriculum materials play a key role in supporting teachers and students in adopting these new methods, which could increase the chance that they will implement the new curriculum the way it was intended by the developers. In other words, the materials can promote the successful implementation of the intended curriculum change. The findings from this study show that although teachers and students have many of the desired knowledge, skills, and attitudes, there are still some gaps that need to be bridged. The guidelines show how curriculum designers can attend to these gaps. Furthermore, it can help them to identify issues that need extra attention, such as the 'need to know' principle and context-based assessment.

Much like any other design process, it is recommended that curriculum designers carry out several pilot tests with the materials. Although the guidelines that are proposed in this study can help designers align their materials with the enactment processes, it remains necessary to try out the materials and make improvements. Moreover, the design guidelines that are proposed in this study, could help the designers in focusing the pilot test toward specific aspects of the design. It can be evaluated to what extend the materials reflect the guidelines and support teachers and students in the development of the desirable knowledge, skills, and attitudes. Based on the findings, there are several issues that teachers and students find specifically challenging. The pilot test should pay special attention to whether the materials support teachers and students in resolving these challenges. Specifically, the pilot test should focus on evaluating to what extend the materials support teachers in applying loose control strategies, support teachers and students in making concepts transferable, support teachers and students in dealing with misconceptions, support teachers in carrying out context-based assessment, and supporting curriculum coherence and (re-)design.

It is recommended that teachers should stay involved throughout the design process and even after. Multiple teachers mentioned that they had used materials that were already fully developed (i.e. design process was finished), but still ran into issues while implementing them in practice. For example, an experiment could have been designed to be appropriate at the time, but as science and technology develop, that may change. Therefore, it is recommended to leave room for feedback and improvements even after the design process has finished and the curriculum materials are published.

5.5 Concluding remarks

The present study offers insights into the knowledge, skills, and attitudes of teachers and students toward the CBE – 5E pedagogy. The findings show the current situation of Dutch teachers and students, and identify the gaps that still need to be bridged to increase the chance of a successful implementation of a context-based curriculum. The data was used to develop guidelines that can be used by curriculum designers internationally, to create materials that pay close attention to teachers and students, and promote the development of their knowledge, skills, and attitudes. Teachers and students reported several concerns regarding the successful implementation of the context-based materials. Not all concerns can be addressed or resolved by curriculum designers, such as the limited available classroom time or being bound to a fixed PTA. What curriculum designers can do, is create materials that pay close attention to the curriculum enactment process by keeping in mind the teacher and student. This way, curriculum designers can develop materials that support teachers and students in adopting new methods and promote the curriculum reform. Subsequently, the theoretical value of CBE – 5E pedagogy can be sustained in practice, making chemistry more interesting and enjoyable for secondary school students.

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7 APPENDICES

7.1 APPENDIX A: HANDOUT 5E INSTRUCTIONAL MODEL

Table 10.

Definition and example of the 5E instructional model for teachers

	Definitie	**Voorbeeld wetenschappelijke onderzoekscontext**
Engage	• Toon interesse in het onderwerp • Laat zien wat je al weet van het onderwerp • Stel vragen als: *"Waarom is dit gebeurd?" "Wat weet ik hier al over?" "Wat kan ik hierover te weten komen?"*	Introductie en opdracht/toepassingscontext: - ziek weefsel en de ontwikkeling van gerichte afgifte van medicijnen - als lid van een onderzoeksgroep, onderzoek doen naar de mogelijkheid om medicijndragers (in de vorm van supramoleculaire nanodeeltjes) alleen medicijnen af te laten geven in het zieke weefsel
Explore	• "Knoei" en puzzel met materialen en ideeën • Voer je eigen onderzoek uit	Literatuur bestuderen en opdrachten maken - het je eigen maken van de benodigde chemische concepten - ondersteunende experimenten uitvoeren en interpreteren - artikelen bestuderen
Explain	• Leg concepten en ideeën uit in je eigen woorden • Baseer deze verklaringen op bevindingen van je onderzoek • Reflecteer en vergelijk je ideeën met anderen	Schrijven van review of onderzoeksvoorstel - over de relevante scheikundige begrippen binnen de ontwikkeling van supramoleculaire nanodeeltjes voor de gerichte afgifte van medicijnen; - ideeën ter verbeteringen van supramoleculaire nanodeeltjes voor de gerichte afgifte van medicijnen.
Elaborate	• Gebruik wat je geleerd hebt om een nieuwe situatie, probleem of idee te verklaren • Trek logische conclusies uit bewijsmateriaal en data	Verdiepen en verbreden van toepassingscontexten - het bestuderen van het maken van de moleculaire bouwstenen die de supramoleculaire nanodeeltjes voor de gerichte afgifte van medicijnen vorm geven - het bestuderen van de vorming van supramoleculaire nanodeeltjes uit de ontwikkelde moleculaire bouwstenen aan de hand van onderzoeksdata - het bestuderen van het gestimuleerd uiteen vallen van supramoleculaire nanodeeltjes aan de hand van onderzoeksdata
Evaluate	• Laat zien dat je een concept begrijpt of dat je een vaardigheid beheerst • Reflecteer op je eigen proces en vooruitgang	Onderzoeksrapportage - schrijven - presenteren

Table 11.

Definition and example of the 5E instructional model for students

<table>
<tr><th></th><th>Definitie</th><th>Voorbeeld wetenschappelijke onderzoekscontext</th></tr>
<tr><td>Engage</td><td>Toon interesse in het onderwerp
Laat zien wat je al weet van het onderwerp
Stel vragen als: “Waarom is dit gebeurd?” “Wat weet ik hier al over?” “Wat kan ik hierover te weten komen?”</td><td>Introductie en opdracht/toepassingscontext:
- ziek weefsel en de ontwikkeling van gerichte afgifte van medicijnen
- als lid van een onderzoeksgroep, onderzoek doen naar de mogelijkheid om medicijndragers (in de vorm van supramoleculaire nanodeeltjes) alleen medicijnen af te laten geven in het zieke weefsel</td></tr>
<tr><td>Explore</td><td>“Knoei” en puzzel met materialen en ideeën
Voer je eigen onderzoek uit</td><td>Literatuur bestuderen en opdrachten maken
- het je eigen maken van de benodigde chemische concepten
- ondersteunende experimenten uitvoeren en interpreteren
- artikelen bestuderen</td></tr>
<tr><td>Explain</td><td>Leg concepten en ideeën uit in je eigen woorden
Baseer deze verklaringen op bevindingen van je onderzoek
Reflecteer en vergelijk je ideeën met anderen</td><td>Schrijven van review of onderzoeksvoorstel
- over de relevante scheikundige begrippen binnen de ontwikkeling van supramoleculaire nanodeeltjes voor de gerichte afgifte van medicijnen;
- ideeën ter verbeteringen van supramoleculaire nanodeeltjes voor de gerichte afgifte van medicijnen.</td></tr>
<tr><td>Elaborate</td><td>Gebruik wat je geleerd hebt om een nieuwe situatie, probleem of idee te verklaren
Trek logische conclusies uit bewijsmateriaal en data</td><td>Verdiepen en verbreden van toepassingscontexten
- het bestuderen van het maken van de moleculaire bouwstenen die de supramoleculaire nanodeeltjes voor de gerichte afgifte van medicijnen vorm geven
- het bestuderen van de vorming van supramoleculaire nanodeeltjes uit de ontwikkelde moleculaire bouwstenen aan de hand van onderzoeksdata
- het bestuderen van het gestimuleerd uiteen vallen van supramoleculaire nanodeeltjes aan de hand van onderzoeksdata</td></tr>
<tr><td>Evaluate</td><td>Laat zien dat je een concept begrijpt of dat je een vaardigheid beheerst
Reflecteer op je eigen proces en vooruitgang</td><td>Onderzoeksrapportage
- schrijven
- presenteren</td></tr>
</table>

7.2 Appendix B: Questionnaire instruments

Vragenlijst context-concept onderwijs docenten

In het Impuls-project ontwikkelen we leermateriaal voor de bovenbouw van het vwo met hedendaags wetenschappelijk onderzoek als uitgangspunt (context). De scheikundige begrippen komen hierbij voort uit deze context. Het doel is om een module te ontwikkelen die een deel van het boek kan vervangen. De module zal opgebouwd worden aan de hand van het 5E-instructiemodel (Engage, Explore, Explain, Elaborate, Evaluate).
Wij willen ervoor zorgen dat de materialen goed aansluiten bij de behoefte in het veld. Hiervoor hebben wij al docenten geïnterviewd en deze vragenlijst helpt ons om in te zien of een groter aantal docenten de perspectieven uit de interviews deelt.
De vragenlijst zal ongeveer 10 minuten duren. Je kunt de vragen beantwoorden op een schaal van 1 (=geheel oneens) tot 5 (geheel eens).

Context-concept generiek

1. De context-concept benadering sluit aan op mijn ideeën over goed onderwijs en wat relevant is voor leerlingen.
2. Ik zou graag willen lesgeven met behulp van de context-concept benadering

Wetenschappelijk onderzoek als context
Een voorbeeld van een actueel onderzoek kan zijn: De ontwikkeling van gerichte afgifte van medicijnen naar ziek weefsel.

3. Het lijkt me interessant om les te geven binnen de context van actueel wetenschappelijk onderzoek.
4. Als ik zelf nog relatief onbekend ben met de wetenschappelijke onderzoek-context, ben ik bereid om daar ter voorbereiding meer over te leren.
5. Ik denk dat het haalbaar is om les te geven binnen een de context van actueel wetenschappelijk onderzoek.

Learning regulation

6. Ik vind het goed als leerlingen zelf de controle hebben over het leerproces (d.m.v. zelf keuzes maken en/of zelf ideeën en materialen te verkennen).
7. Ik kan goed lesgeven door de leerlingen te begeleiden, ondersteunen en faciliteren, zonder centraal de leiding te moeten nemen.

Teaching emphasis

8. Ik vind dat de nadruk bij scheikunde onderwijs moet liggen op het aanleren van de benodigde concepten om scheikunde te begrijpen.
9. Ik vind dat de nadruk bij scheikunde onderwijs moet liggen op het ontwikkelen van inzicht in hoe scheikunde werkt, en hoe kennis in scheikunde opgebouwd is.
10. Ik vind dat de nadruk bij scheikunde onderwijs moet liggen op het oplossen van sociale/maatschappelijke problemen, waarbij scheikundige aspecten betrokken zijn.

(re-)design of curriculum materials

11. Ik ben bereid om tijd te besteden aan het aanpassen van een module, zodat deze aansluit op mijn onderwijspraktijk.
12. Ik voel mij voldoende bekwaam om een module aan passen, zodat deze aansluit op mijn onderwijspraktijk.

CBE advocate

13. Mijn school biedt mij de ondersteuning om onderwijsinnovaties toe te passen in mijn onderwijspraktijk.
14. Ik zou bereid zijn om (indien nodig) als een vertegenwoordiger te fungeren voor context-concept onderwijs.

5E-instructiemodel generiek

15. Ik heb ervaring met het lesgeven aan de hand van het 5E-instructiemodel.
16. Ik zou het 5E-instructiemodel graag willen gebruiken.

Engage

17. Het lijkt mij gemakkelijk om ervoor te zorgen dat leerlingen betrokken raken bij het onderwerp, wanneer zij dit leren binnen een context.

Explore

18. Ik vind het belangrijk dat leerlingen eerst zelf gaan experimenteren met ideeën en materialen, voordat zij de uitleg krijgen.
19. Ik maak mij geen zorgen dat leerlingen misconcepties krijgen wanneer zij eerst zelf gaan experimenteren met ideeën en materialen.

Explain

20. Ik denk dat leerlingen de concepten beter begrijpen wanneer zij deze zelf ontdekken.
21. Ik vind het vaak nodig om centrale concepten in de les klassikaal uit te leggen.
22. Ik ben in staat om het in te schatten wanneer ik leerlingen van informatie/uitleg moet voorzien, zodat zij verder kunnen werken.

Elaborate

23. Ik vind het belangrijk dat leerlingen begrijpen hoe concepten kunnen worden toegepast in meerdere contexten.
24. Ik vind het gemakkelijk om de verbindingen tussen concepten en contexten zichtbaar te maken voor de leerlingen.

Evaluate

25. Ik zou graag een module implementeren waarin leerlingen hun kennis laten zien door middel van een tentoonstelling, onderzoeksrapportage, of presentatie.
26. Ik vind het gemakkelijk om te beoordelen wat een leerling heeft geleerd in een tentoonstelling, onderzoek rapportage of presentatie.

Achtergrondinformatie

1. Leeftijd:

2. Aantal jaren leservaring:
3. Ervaring met werken met modules buiten het lesboek om: Geen/weinig – enigszins – veel
4. Lesmethode(s) die ik in mijn onderwijs gebruik: _____
5. Ik ben benieuwd naar hoe mijn leerlingen denken hierover, en ben bereid om mijn leerlingen een vragenlijst hierover te laten invullen: Ja/nee

Einde vragenlijst

Bedankt voor het invullen van de vragenlijst, indien je de laatste vraag met 'ja' hebt beantwoord zullen wij binnenkort contact met je opnemen om de leerling-vragenlijsten met je te delen.

Suggesties, wensen of overige opmerkingen:

<u>Vragenlijst context-concept onderwijs leerlingen</u>

Op de Universiteit Twente zijn wij bezig om nieuwe leermodules voor scheikunde te ontwikkelen, met hedendaags wetenschappelijk onderzoek als uitgangspunt (context). Zo’n context kan bijvoorbeeld zijn: de gerichte afgifte van medicijnen aan kankerpatiënten. De scheikundige begrippen komen hierbij voort uit deze context. Wij noemen deze manier van leren: Chemie in context. Met behulp van jullie input willen wij ervoor te zorgen dat die modules zo goed mogelijk aansluiten op de praktijk. De vragenlijst zal ongeveer 10 minuten duren.

1. Ik heb al voor het invullen van deze vragenlijst scheikunde geleerd met hedendaags wetenschappelijk onderzoek als uitgangspunt.
2. De Chemie in context aanpak sluit aan bij de manier waarop ik graag scheikunde leer.
3. Het lijkt mij interessant om meer te weten te komen over actueel wetenschappelijk (universitair) onderzoek.
4. Doordat begrippen worden behandeld binnen een concrete context, denk ik dat ik me beter besef waarvoor ik scheikunde leer.
5. Doordat begrippen uitgelegd worden binnen een concrete context, denk ik dat het voor mij gemakkelijker is om te herkennen hoe begrippen met elkaar samenhangen.
6. Ik denk dat de Chemie in context aanpak mijn motivatie zal verhogen.
7. Ik denk dat ik betere cijfers zal halen als ik scheikunde leer volgens de Chemie in context aanpak.

Actief & zelfstandig leren

8. Ik ben in staat om zelfstandig te werken en zelf keuzes te maken in mijn leerproces.
9. Ik ben meer gemotiveerd om te leren wanneer ik zelf keuzes mag maken.
10. Ik vind het belangrijk dat het duidelijk is wat de docent van mij verwacht tijdens de les.
11. Ik vind het belangrijk dat er een duidelijke structuur zit in het lesmateriaal.

Onderzoek vaardigheden

12. Ik ben in staat om zelfstandig scheikundige experimenten/proefjes uit te voeren.
13. Ik ben in staat om conclusies te trekken aan de hand van experimenten/proefjes.

14. Ik werk graag tijdens scheikunde lessen aan practica.

Samenwerkend leren

15. Ik werk meestal liever alleen dan in een groepje.
16. Door te overleggen met mijn groepsgenoten kan ik meer leren over scheikunde.
17. Ik begrijp het beter wanneer mijn klasgenoten begrippen uitleggen, dan wanneer de docent ze mij uitlegt.

Engage

18. Door te leren binnen de context van actueel wetenschappelijk onderzoek, zal ik snel betrokken raken bij de les.

Explore

19. Het lijkt mij leuk om eerst verkennende proefjes uit te voeren, voordat ik details weet over het onderwerp om zo kennis te maken met het onderwerp.
20. Het lijkt mij verwarrend om proefjes uit te voeren voordat ik details weet over het onderwerp, omdat ik dan nog niet weet waar ik op moet letten.

Explain

21. Ik vind het moeilijk om uit te leggen wat ik in een experiment/proefje heb waargenomen.
22. Ik vind het belangrijk dat de docent altijd belangrijke scheikundige begrippen klassikaal uitlegt.

Elaborate

23. Ik vind het leerzaam om geleerde begrippen toe te gaan passen in een nieuwe context.

Evaluate

24. Ik zou het fijn vinden om beoordeeld te worden aan de hand van een presentatie, tentoonstelling of onderzoek rapportage.
25. Ik vind dat ik via een proefwerk het beste kan laten zien wat ik heb geleerd.

Achtergrondinformatie

De resultaten van deze vragenlijst worden anoniem verwerkt. Het kan overigens voor de verwerking van de resultaten interessant zijn om wat achtergrondinformatie te hebben.

1. Leeftijd:
2. Leerniveau en leerjaar:

Einde vragenlijst

Bedankt voor het invullen van de vragenlijst.

Suggesties, wensen of overige opmerkingen over het onderzoek: _____

7.3 Appendix C: Design guidelines for curriculum materials

Design guidelines for context-based chemistry curricula

	Why?	What?	How?
1 Support for learning methodology	Lesson Preparation		
	Teachers struggle with: - determining need for just-in-time (JIT) information - loose control strategies - student monitoring	- Include important JIT information - Support teachers in applying loose control strategies - Support teachers in monitoring students' progress (e.g. glossary, log book).	*JIT: Before students start working on experiment A, make sure to explain principle X. This will help students understand the experiment better, and will steer their observations towards this principle, making the experiment more meaningful.*
	Both students and teachers are worried about misconceptions in CBE.	- Include common misconceptions and ways to deal with these (e.g. challenge misconceptions in the appropriate way)	*For this concept, it is common that students believe X. To deal with this misconception, show the student that X does not hold up in a different situation. Then, explain that Y is more plausible, because it does solve the problem here.*
2 Support for assessment	Context-based Assessment		
	Teachers and students sometimes fail to see the relevance of context-based assessment. Different teachers prefer different assessment methods.	- Describe the rationale behind context-based assessment methods - Provide teachers with various options for context-based assessment methods	Context-based testing assesses and promotes students' higher-order thinking skills (e.g. problem solving and inquiry skills). Also, learning outcomes may improve if the assessment method is aligned with the teaching methods.
	Transfer of Concepts		
	Teachers and students consider the elaboration phase as the most difficult to implement, because of the transfer of concepts	- Support teachers and students in making concepts transferable - Include a formative test before the elaborate phase, to assess students' (growing) understanding of a concept	*Before starting the elaborate phase, ask students to explain phenomenon C. If they can explain this by using principles X and Y, they understand how these principles are applied within this context.*
3 Practicality	Congruence		
	Teachers struggle with: - determining need for just-in-time (JIT) information - loose control strategies - student monitoring	- Include important JIT information - Support teachers in applying loose control strategies - Support teachers in monitoring students' progress (e.g. glossary, log book)	*JIT: Before students start working on experiment A, make sure to explain principle X. This will help students understand the experiment better, and will steer their observations towards this principle, making the experiment more meaningful.*
	Supporting Curriculum Coherence		
	Many teachers argue that coherence with their existing course book is imperative.	- It should be made clear how the new curriculum fits into the existing curriculum based on the chemistry topics that are covered.	*This module will cover concept: (…). This concept is explained in book chapter(s) 2..4, 2,5 and 4.1 in course book A, and 2.3 and 2.4 in course book B (etc.).*

Supporting Curriculum (re-)Design

Experienced teachers are confident of their ability to adjust the materials based on their teaching practice and their learners' needs, but inexperienced teachers are less confident. The materials should be both adaptable and meaningful.	- Allow multiple points of access - Emphasize key building blocks rather than procedural steps - Explain the rationale behind instructional resources, but allow for use in different settings.	*For each phase of the 5 E instructional model, we made an outline of the corresponding learning activities. You can choose to implement these lessons as they are, or move between the phases more flexibly based on your students' level, or the amount of available time*

4 Support for Science Topics

Topic-Specific Scientific Phenomena

Experiments should not neglect the practical implementation. The scientific research context should make concepts accessible for students.	- Experiments should include a rationale, possible pitfalls and should work properly. The materials should describe how the experiments can be used in practice. - Research context should be written on a student-level.	*Experiment A can be used to illustrate principle X. You can use it as a class demonstration to focus students' attention towards this specific principle. When students see the effects of experiment A, they will understand that (…).*

Students' Ideas About Science

Both students and teachers are worried about misconceptions in CBE.	- Include common misconceptions and ways to deal with these (e.g. challenge misconceptions in the appropriate way)	*For this concept, it is common that students believe X. To deal with this misconception, show the student that X does not hold up in a different situation. Then, explain that Y is more plausible, because it does solve the problem here.*

5 Support for Scientific Inquiry

Engaging Students in Questions

Teachers and students sometimes fail to see the relevance of context-based assessment. Different teachers prefer different assessment methods.	- Describe the rationale behind context-based assessment methods - Provide teachers with various options for context-based assessment methods	*Context-based testing assesses and promotes students' higher-order thinking skills (e.g. problem solving and inquiry skills). Also, learning outcomes may improve if the assessment method is aligned with the teaching methods.*

Engaging Students with Collecting and Analysing Data

Teachers and students consider the elaboration phase as the most difficult to implement, because of the transfer of concepts	- Support teachers and students in making concepts transferable - Include a formative test before the elaborate phase, to assess students' (growing) understanding of a concept	*Before starting the elaborate phase, ask students to explain phenomenon C. If they can explain this by using principles X and Y, they understand how these principles are applied within this context.*

Engaging Students in Making Explanations Based on Evidence & Promoting scientific communication

Teachers often prefer giving plenary class explanations. Other strategies may be more beneficial for CBE.	- Include recommendations for how teachers can support students in generating explanations in various ways, as well as the rationale behind these recommendations - Students could write about their process in a logbook	*Ask students to write down their explanation of phenomenon B. After that, let the students discuss in groups. Through these discussions, students will think critically about alternative explanations.*

6 Support for Subject Knowledge

Development of Subject Matter Knowledge

Teachers are confident of their ability to familiarize themselves with contexts and concepts, but do not want to spend too much time on this.	- Provide teachers with elaborate information about the (scientific research) context - Support teachers with elaborate subject matter information	*In this module, the scientific research of (…) is used as a context. This research is currently being conducted at the University of Twente in Enschede, and focuses on (…). To learn more about this research, go to [website].*