CONTEXT-BASED CHEMICAL EDUCATION: HOW TO IMPROVE IT?

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Introduction

Chemical education reform is under way in many countries. An important reason for this reform is the growing dissatisfaction with the position of many chemistry curricula: quite isolated from students' personal interest, from current society and technology issues, and from modern chemistry. One of the efforts to abolish current curriculum isolation is the use of meaningful contexts for teaching and learning chemistry. From the 1980s, context-based curriculum projects were implemented in mainstream chemistry courses, for instance, the USA project of 'Chemistry in the Community' (ChemCom) and the UK project of 'Salters Chemistry'. Quite recently, new projects were implemented, such as the USA project of 'Chemistry in Contexts: Applying Chemistry to Society' (CiC), and the German project of 'Chemie im Kontext' (ChiK). Contexts were adopted to encourage a more positive attitude and a better understanding of chemistry. However, it appears that the implementation of contexts-based courses is not as simple as it looks like, and effects on students' understanding of chemistry concepts are somewhat disappointing. The present paper discusses some important conditions for improving context-based chemical education.

Contexts: where are they come from?

Contexts can be defined in several ways. Very often, contexts are described as situations that help students to give meaning to concepts, rules, laws, and so on. This definition can be expanded by the notion that contexts can also be described as practices that help students to give meaning to activities in the school laboratory. Nevertheless, these definitions are quite general. In my opinion, we need more precise descriptions to improve the clarity of discussions about contexts and their use in chemical education. A more precise way of defining consists of looking at the domains of origin of contexts. I would make a distinction between the following four domains of origin (see Table 1).

The personal domain. Contexts taken from this domain are important because schools should contribute to the personal development of students by connecting chemistry with their personal lives. Many everyday life issues are useful. For instance, the context of personal health care can be related to poisonous effects of substances on the body in terms of biochemistry processes, and the context of personal body lotions can be linked with the chemical characteristics of the components of these liquids

The social and society domain. Contexts taken from this domain are important because schools should contribute to prepare students for their roles as responsible citizens by clarifying chemistry and its role in social issues. Many of these issues can be used. For instance, the context of acid rain effects on the environment can be connected with the chemical topics of acid -metal reactions and neutralization reactions, and the context of climate changes can be related to the chemistry of combustion processes or reactions between radicals in the ozone layer of the atmosphere.

The professional practice domain. Contexts taken from this domain are relevant because schools should prepare students for their coming role as professional workers in public or private areas. Several practices are useful. For instance, the practice of chemical engineers can be linked with small scale designing and testing of industrial processes, such as the small scale production of glues or polymers, and the practice of chemical analysts can be related to the chemical topic of investigating the quality of water, food, or medicines.

The scientific and technological domain. Contexts taken from this domain are relevant because schools should contribute to the development of scientific and technological literacy of students. Several issues can be used, especially issues that clarify scientific ways of handling and reasoning. For instance, the context of scientific research methods can be connected with open-inquiry in the school lab, and the context of paradigm shifts in meaning of models and theories in chemistry can be related to the development of acid-base models (e.g. models of Arrhenius, Brønsted, and Lewis) or the shift from the old phlogiston theory towards modern oxidation theories.

Finally, it will be clear that a particular context can be taken from more than one domain. For instance, the context of consumption of food can come from the personal domain as well as from the social and society domain.

Table 1. Four origins of contexts

Origin of a context	Example of a context
* Personal domain	* Personal health care
* Social and society domain	* Acid rain effects on the environment
* Professional practice domain	* Practices of chemical engineers
* Scientific and technological domain	* Historical models and theories

Teaching approaches and functions of contexts

In teaching, the order of presentation of contexts and related concepts can vary, and, for that reason, the function of contexts can also vary (see Table 2). In many

traditional context-based approaches, contexts follow concepts. For instance, after teaching the first ten hydrocarbons (from methane to decane), the role of these hydrocarbons in society is addressed. In this teaching, contexts often have two functions. Firstly, contexts are presented as illustrations of concepts that already have been taught, especially in the case of abstract concepts. Secondly, contexts are presented to offer the possibility to students of applying their knowledge of a concept. This can lead to the transformation of the existing meaning of a concept or to the addition of a new meaning to the concept.
In many more modern context-based approaches, contexts precede concepts. For instance, a discussion about environmental pollution and the combustion of petrol in cars and airplanes is followed by addressing the main components of petrol and their chemical characteristics. In this teaching, two other functions of c ontexts are often emphasized. Firstly, contexts are presented as the starting point or rationale for teaching concepts. Secondly, these contexts not only have an orienting function, but can also enhance motivation for learning new concepts. In some most re cent context-based approaches, contexts not only precede concepts but these concepts are also followed by (other) contexts (see Table 4). In this teaching, the four functions of contexts are combined.

Table 2. Context-based approaches and functions of contexts

Teaching approach	Order of presentation	Function of context
* Traditional	* Contexts follow concepts	* Illustration * Application
* More modern	* Contexts precede concepts	* Orientation * Motivation
* Recent	* Contexts precede concepts and (other) contexts follow them	* All functions mentioned above

Effects of context-based approaches

Most of the studies of effects of context-based approaches in chemical education focus on students' learning outcomes, and students' motivation and attitud e. The research results show that it is not easy to come to a unanimous judgment about these effects. I will clarify this by presenting results of some exemplar studies below.

Some studies indicated that there is hardly any advantage of context-based courses in terms of the development of students' understanding. For instance, Ramsden (1997) compared the effects of a context-based course and a more traditional course to British high school students' understanding of key chemistry concepts. Her study indicated that there is little difference in levels of understanding of concepts as element and compounds, chemical reaction, and the Periodic Table. In contrast, other studies reported some advantages to students in context-based courses in terms of their understanding. For instance, Barker and Millar (2000) undertook a comparative study of British high school students following a context-based course or a conventional course. They found a slight advantage in developing understanding (about chemical thermodynamics and chemical bond) of students in the context-based course. Nevertheless, they also reported the tenacity of a number of misunderstandings among students of both groups. Some studies also looked at effects on students' motivation and attitude. The comparative study of Ramsden (1997), dealing with British high school chemistry students, showed some benefits associated with a context-based approach in terms of stimulating students' interest in chemistry. Sutman and Bruce (1992) noted that North-American high school students were much more willing to engage with context-based chemistry materials than with more traditional materials.

A summarizing meta-analysis of 66 studies of the effects of context-based (and science-technology-society) approaches is given by Bennett, Hogarth and Lubben (2003). They reviewed studies of approaches in the teaching of secondary school science that used contexts as the starting point for the development of scientific ideas. The majority of the courses under consideration came from the USA (e.g. the ChemCom project), the UK (e.g. the Salters Chemistry project), the Netherlands (e.g. the PLON project) and Canada (several STS projects). The meta-analysis showed the following interesting results:
(i) There is some evidence to support the claim that context-based approaches motivate students in their science lessons and enhance more positive attitudes to science more generally.
(ii) There is good evidence to support the claim that context-based approaches do not adversely affect students' understanding of scientific ideas.

In conclusion, the reported outcomes of context-based approaches are positive from an affective development perspective, but they are somewhat disappointing from a cognitive development point of view. The absence of effects on learning outcomes can be caused by a weak relationship between contexts and relevant concepts in the perception of students and teachers. This situation underlines the need for improving context-based teaching.

How to improve context-based chemistry teaching?

In the last section, I will address some important conditions for improving context-based teaching from three different perspectives: (i) the student, (ii) the professional development of teachers, and (iii) the curriculum.

From *the student perspective*, I would point out the importance of selecting adequate contexts for incorporating in student courses, especially when contexts are used as starting points for teaching concepts. These contexts should take into account students' specific difficulties in relating contexts to concepts. These difficulties have different possible causes. First, the contexts may be not really be relevant for students

and will not motivate them to study the chemistry content. For instance, the use of a technological context as the construction of chemical weapons will not stimulate many school girls to study the accompanying chemistry, while the use of a personal life context as the properties and composition of several kinds of lipsticks and other cosmetics will not be an interesting issue for many school boys. Second, and in contrast with the former cause, the contexts can be so interesting that they distract students' attention from the related concepts. Third, the contexts can be too complicated for students to help them to make proper links with concepts. Finally, the contexts can be confusing for students, because everyday life meanings of topics do not always correspond with science meanings. For instance, the acidity of acid rain is expressed in a number (pH); in everyday life, people will reason that a high acidity will correspond with a high number, but in science this acidity should have a low number.
In conclusion, an important condition for improving context-based chemistry teaching is a careful selection of contexts. Some criteria for selecting adequate contexts are given in Table 3. Finally, I will argue that the introduction and use of contexts should be accompanied with a lot of care for bridging the gap between meanings of concepts in a daily life context and meanings of these concepts in a chemistry context.

Table 3. Criteria for selecting adequate contexts

Characteristics of adequate contexts
* Contexts should be well-known and relevant for students (girls and boys)
* Contexts should not distract students' attention from related concepts
* Contexts should not be too complicated for students
* Contexts should not confuse students

From *the teachers' professional development perspective*, I would point out the importance of helping teachers to undertake context-based teaching in a successful way. In a study of a teacher development course for teaching chemistry concepts in contexts, Stolk, Bulte, De Jong and Pilot (2005) found that it is quite difficult for experienced teachers to link an introductory context with chemistry content. The introductory context dealt with properties of diapers for babies and included a student experiment to find out the maximum amount of water that can be absorbed by a diaper. The students were surprised to observe the unexpected big amount of water uptake (about one litre) by the diaper (for a baby of three years old). The aim of this experiment was to evoke students' 'need-to-know' about the chemistry beyond (property-structure relations of polymer networks). However, after the experiment, the teachers did not use students' questions about the phenomena as a starting point for linking with chemistry concepts, but referred directly to a general chapter about organic chemistry in the students' textbook. In other words, after the introductory experiment, they taught according to their familiar routines. This teaching did not

contribute to enhance the relationship between the introductory context and related concepts.
In conclusion, teachers' professional development courses should relate course activities with context-based teaching practices at school. In my opinion, it is very important that teachers get the opportunity to discuss and reflect on teaching experiences with linking contexts with concepts. An illustrative example of an in-service course for chemistry teachers who want to learn to enhance this relationship is given by Stolk, Bulte, De Jong and Pilot (2006). In this course, teachers prepared, enacted, and evaluated lessons that include the use of a context-based unit. In this unit an introductory context as well as a follow-up inquiry context was given. The strategy that the teachers used for context-based teaching is summarized in table 4. The project is still evolving, and, for that reason, it is too early to evaluate the value of this strategy properly.

Table 4. Strategy for context-based teaching

Phase of context-based teaching	Aim of the phase
* Offering an introductory context	* Evoking students 'need-to-know', that is, students' questions
* Collecting and adapting students' questions	* Preparing students for finding answers by learning about relevant concepts
* Restructuring textbook content or selecting website information	* Enhancing links between the questions and information in textbooks or website
* Offering a follow-up inquiry context	* Evoking students 'need-to-apply' their knowledge

From *the curriculum perspective*, I would point out the importance of a proper position of contexts in chemistry curricula. The structure of many modern curricula is still based on the conventional relationship between school chemistry topics; contexts do not have a central position. Because of this situation, students and teachers are not inclined to take contexts very seriously. For instance, when contexts are used as post-theory illustrations of topics, many students do not see these illustrations as meaningful, because of their experience that very often the illustrations are not incorporated into testing and assessment. Moreover, teachers often consider the contexts in textbooks as useful for learning but they see the teaching of them as too time-consuming and skip many of them.
In conclusion, an important condition for improving context-based chemistry teaching is a more dominant position of contexts in curricula, but without loss of attention to chemistry concepts. It is my opinion that this can be realised by developing curricula in which contexts are the lead in determining the curriculum structure of chemistry topics.

Finally, I would emphasize the importance of combining courses for chemistry teachers with chemical education research. Up till now, many context -based innovation projects mainly focus on the development and implementation of new materials. In the near future, more attention should be given to accompanying research projects for investigating the value of context-based chemical education. In this field, special attention should be given to factors that contribute to improve students' understanding of chemistry topics.

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