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Chemistry in crisis? Perspectives on teaching and learning chemistry in Swedish upper secondary schools

Abstract

Explanations for a decline in the number of students studying chemistry at advanced level all over the world have been sought for quite some time. Many students do not find chemistry relevant and meaningful and there have been difficulties in developing school chemistry courses that engage students sufficiently and tempt them to further studies in the field. In this study, Swedish upper secondary school students (N_s=372) and their teachers (N_t=18) answered a questionnaire on their experiences of the content and the working methods of their chemistry course. They were also given the opportunity to express ideas on how to make chemistry courses more interesting and meaningful. The results point out some subject areas as both easy and interesting, e.g. atomic structure; while other areas are hard to understand but still interesting, e.g. biochemistry. The students find chemistry lessons teacher-centred, something they appreciate. When teachers and students gave suggestions on how to improve the relevance of chemistry education at upper secondary level, more laboratory work and connections to everyday life were the most common proposals. But on the whole, these students seem quite satisfied with their chemistry courses.

Background

In many countries, as in Sweden, there has been a decline in the number of students studying chemistry at the university level. Many studies have tried to explain why students, when leaving upper secondary school, are not interested in taking chemistry at the tertiary level. The low interest has, of course, not only one cause but is attributed to a number of different reasons. Twenty-five countries from all over the world have in a project presented their educational systems focusing on chemistry education (Risch, 2010). Even though some countries have successful educational systems according to international tests like PISA and TIMSS (e.g. Finland and Singapore), most of the 25 countries report on students with negative opinions about chemistry. One of the conclusions drawn from the project is that countries with successful educational systems seem to have competent teachers who want to work as teachers (Risch, 2010). The importance of teachers is also emphasized by many other researchers (e.g. Osborne & Dillon, 2008).

The relevance of chemistry

Unfortunately, science and especially chemistry courses are often felt to be irrelevant to students' everyday life (Aikenhead, 2006; Bennett, Gräsel, Parchmann, & Waddington, 2005; Bulte, Westbroek, de Jong, & Pilot, 2006; Gilbert, 2006; Hofstein & Kesner, 2006; Millar, 2006; van Aalsvoort, 2004a, 2004b). Aikenhead (2006) argues that science content included in school courses seldom is applicable in everyday life, and most students have problems finding the science content meaningful even though the context in itself might be relevant. The lack of relevance in chemistry has been studied from many different starting points. van Aalsvoort (2004a; 2004b) has analysed chemistry education from two different theoretical perspectives, activity theory and logical positivism, and shows that the former has a potential to connect knowledge with practice which makes chemistry more functional, multi-perspective and situated. From these results he has written a chemical education textbook with the activity theory as starting point and claims that it solves the problem of lack of relevance. In another effort to make chemistry studies more relevant, context-based chemistry courses have been developed (Bennett & Lubben, 2006; Bulte et al., 2006; Gilbert, 2006; Hofstein & Kesner, 2006; Parchmann et al., 2006).

The difficulty of chemistry

Besides the problem of relevance, there is a belief that science is very difficult to study (Bennett et al., 2005; Bulte et al., 2006), and there is also an apparent curriculum overload in science courses (Bennett et al., 2005; Gilbert, 2006). The overload problem seems to be an issue for both conventional and more context-based courses (Bennett et al., 2005). In order to understand why students find science difficult, research projects have tried to reveal the main obstacles. Misconceptions and problems with models and modelling are often mentioned as important impediments for students (de Jong & Taber, 2007; Gilbert & Treagust, 2009). Concerning models, many different areas within chemistry have been studied and problems with visualization of models have been established (de Jong & Taber, 2007; Gilbert, Reiner, & Nakhleh, 2008). It is a challenge for students to move between the different levels used to visualize models, the 'triplet levels' defined by Johnston (i.e. macro, sub-micro and representational levels). Gilbert and Treagust (2009) discuss these triplet levels, and they show the problems students have in understanding the relationship between the levels: i.e. difficulties in moving between the three levels; misconceptions particularly with regard to the sub-micro level; no connection to the observable macro level; and to understand the complex rules used at the representational level. Drechsler (2007) describes students' and teachers' difficulties with models in the specific area of acids and bases. He claims that teachers often do not emphasize the different models (e.g. Lowry-Brønsted model and Lewis model) to describe acids and bases, and this mix of models makes it complicated for students to understand the chemistry content. The textbook is an important source of content knowledge, and it is essential for textbooks to clearly explain the different models, not giving a too simplified or over-generalized picture (Aikenhead, 2006; Drechsler, 2007; Nelson, 2006). Models, modelling and visualization are fundamental and a competent chemist must be able to move freely between these levels of representation.

Interest in chemistry

For these reasons, many countries are experiencing problems of engaging students in advanced study of natural science, especially chemistry and physics. Schreiner and Sjøberg (2007) refer to several studies which identify subject interest as a key criterion, and even though students' abilities are important, high-achievers do not choose to study science further at the university level. Students in Western countries seem to show less interest in school science than students from less economically-developed countries (Schreiner & Sjøberg, 2007). In a research project on Swedish ROSE-data, secondary students' opinions about the science content and their science lessons were investigated (Jidesjö, Oscarsson, Karlsson, & Strömdahl, 2009). They found students' interest to be partly gender-dependent, but claim that students in late secondary school in general want to learn about areas like health, diseases and space. Areas more directly associated with chemistry, for instance response options like 'atoms and molecules', are marked as one of the least interesting by students in the ROSE-study (Jidesjö et al., 2009; Schreiner, 2006). There is, of course, a question of interpretation regarding what students define as school chemistry; health can obviously be perceived as chemistry. We can therefore conclude that there is still a need to investigate in more detail students' opinions about chemistry, first of all we have to learn about what students classify as chemistry and thereafter we have to discuss what can be done to improve the current situation with just a few students studying chemistry at tertiary level.

Aim and research questions

The aim was to investigate opinions about chemistry held by students and their teachers at the Natural Science Programme after completing their compulsory chemistry courses. This paper addresses the questions:

- *Which areas of chemistry do upper secondary school students find difficult or easy, interesting or not interesting?*
- *How do students apprehend the working methods during their chemistry lessons, and what recommendations do students and teachers suggest for making chemistry in upper secondary school more meaningful and interesting?*

It is important to point out that the students' thoughts about the different areas are not explicitly related to their achievements.

Sample and sample size

The Swedish upper secondary school

This study is carried out in the Swedish upper secondary school which consists of 17 national programmes. Chemistry is studied primarily by students at the Natural Science and the Technology Programmes. According to statistics from the Swedish National Agency for Education about 11,5 percent of a class cohort studied the Natural Science Programme and 5 percent the Technology Programme in the 2009/2010 school year (Swedish National Agency for Education, 2010). Age groups in Sweden at upper secondary school is currently about 130 000 students (Swedish National Agency for Education, 2010). The Swedish upper secondary school has a course-based curriculum; students have some compulsory courses and others are optional. Within chemistry, there are three chemistry courses; Chemistry A, B and an extension course. Depending on programme, different courses are compulsory or optional. At present, about half of the students who take the A-course also take the B-course and only a fraction of the students take the extension course (Swedish National Agency for Education, 2010).

Selection and data acquisition

A questionnaire was completed by N_s=372 upper secondary students (N_s=163 female and N_s=206 male) and their N_t=18 chemistry teachers at the Natural Science Programme. A translation of the student and teacher questionnaires are available in Appendix A and B. The students, aged 18-19 years, had just finished their compulsory A- and B-chemistry courses. The selection of respondents was not entirely random since the questionnaire was sent to interested chemistry teachers who participated voluntarily. Teachers were selected from contacts through the Swedish Chemical Society, and the questionnaire was distributed to eight schools in five towns in different parts of Sweden. All teachers contacted volunteered and all students who were present at the lesson, when the questionnaire was filled out, took part in the study. Students and teachers completed the questionnaire anonymously.

Method

The questionnaire

Both students and teachers were asked similar questions about their opinions on chemistry. From the syllabi for the A- and the B-course in chemistry (Swedish National Agency for Education, 2000) ten different headings – in this article named areas – were chosen as response options (i.e. atomic structure, chemical bonding, chemical calculations & stoichiometry, chemical equilibrium, organic chemistry, biochemistry, acids & bases, energy/enthalpy, oxidation & reduction, and chemical analysis). The areas were chosen based on the syllabi and from the content presented in different chemistry textbooks (Lüning, Nordlund, Norrby, & Peterson, 2009; Pilström et al., 2007). The chemistry content in these textbooks is similar to content studied in other countries (Risch, 2010).

In the first part of the questionnaire, the students were asked which three areas they found easy or difficult, and most interesting or least interesting. Teachers were asked questions about what they considered easy or difficult to teach and their opinions of students' views about the different areas. The teachers were also given an opportunity to explain their thoughts about their students' views.

The second part of the student questionnaire consisted of questions about working methods in the classroom; student-centred approaches (e.g. 'students do laboratory work' or 'teacher and students discuss together') and more structured teacher-directed approaches (e.g. 'teacher talks and asks questions' or 'teacher is demonstrating something'). These questions considering working methods were copied from the latest Swedish national evaluation for compulsory school for possible future comparisons (Swedish National Agency for Education, 2004). The students' experiences about how they best learn chemistry were compared to how often the different working methods were used. The teachers were not asked about the working methods in their questionnaire.

At the end of the questionnaire, both students and teachers were given an open question about how chemistry education could improve and become more meaningful and interesting.

Data analysis

The empirical data were gathered; percentages were calculated and analyzed with SPSS 18.0. Since students and teachers were instructed to select three areas out of ten as easy, difficult and more or less interesting respectively, the sum of percent within each category is 300. As a consequence of some students only marking two areas instead of three, the sum in three of the categories (difficult, most interesting and least interesting) falls below 300.

Results

Students' view of different areas in chemistry

The most obvious result is that 82% of the students in this study identified 'atomic structure' as easy when asked to choose three easy areas in chemistry out of the ten selected areas. 'Acids & bases' and 'chemical calculations & stoichiometry' were likewise considered moderately easy (42% and 36% respectively). On the other hand, 'analytical chemistry', 'energy/enthalpy' and 'biochemistry' were considered difficult (44%, 41% and 40% respectively). The areas marked as easy or difficult

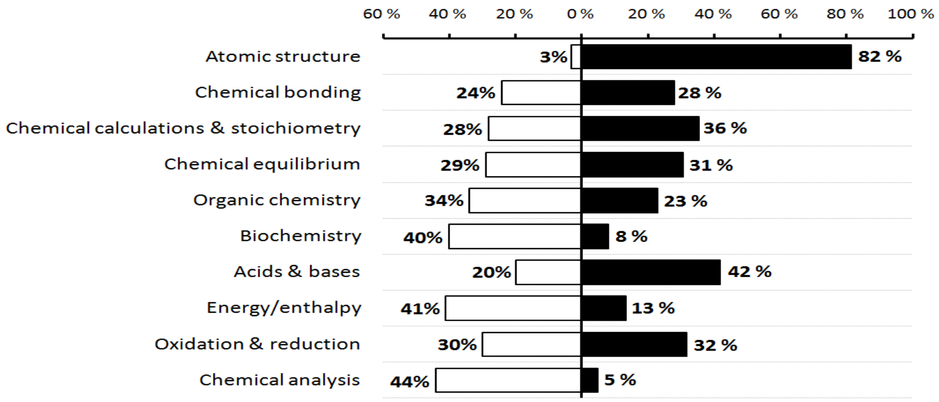

Figure 1. Students' (N_s=372) answers in percent indicating the three areas they found easiest and most difficult respectively. Areas identified as easy are marked black and difficult areas are marked white.

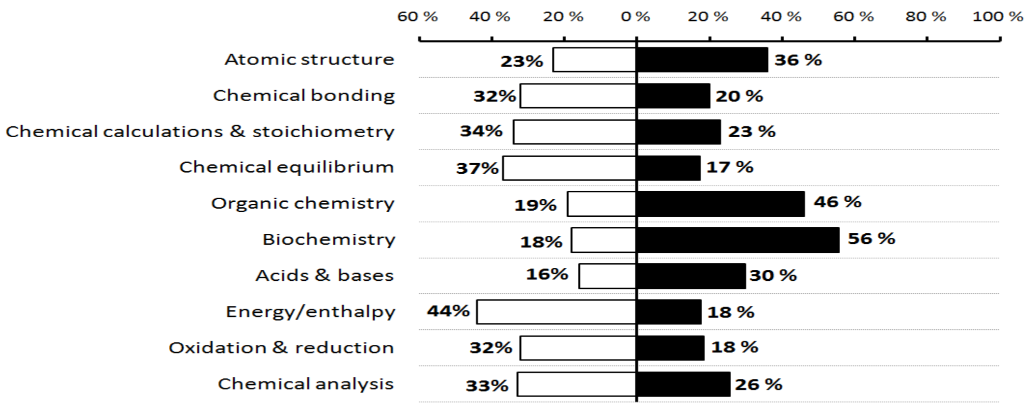

Figure 2. Students' (N_s=372) answers in percent indicating the three areas they found most and least interesting respectively. Areas identified as most interesting are marked black and least interesting areas are marked white.

are presented in figure 1. When discussing interesting areas, the students stated 'biochemistry' and 'organic chemistry' as most interesting (56% and 46% respectively) and 'energy/enthalpy' as least interesting (44%). The students' interests in the areas are presented in figure 2. There were minor gender differences in students' view of the different areas and therefore no detailed results are presented. Crosstabulation of the aforementioned areas show small differences between boys and girls (range between 45 and 55%) with one exception, the opinion that biochemistry is a difficult area, where 61% are boys and 39% are girls.

Teachers' view of different areas in chemistry

The students' teachers (N_t=18) were asked which areas they themselves found easy or difficult to teach, and the result was almost unanimous. Most teachers (N_t=14) found it easy to teach 'atomic structure', 'chemical calculations & stoichiometry' and 'oxidation & reduction' because these areas have many simple and clear rules to follow. The teachers thought it was difficult to teach 'bioche-

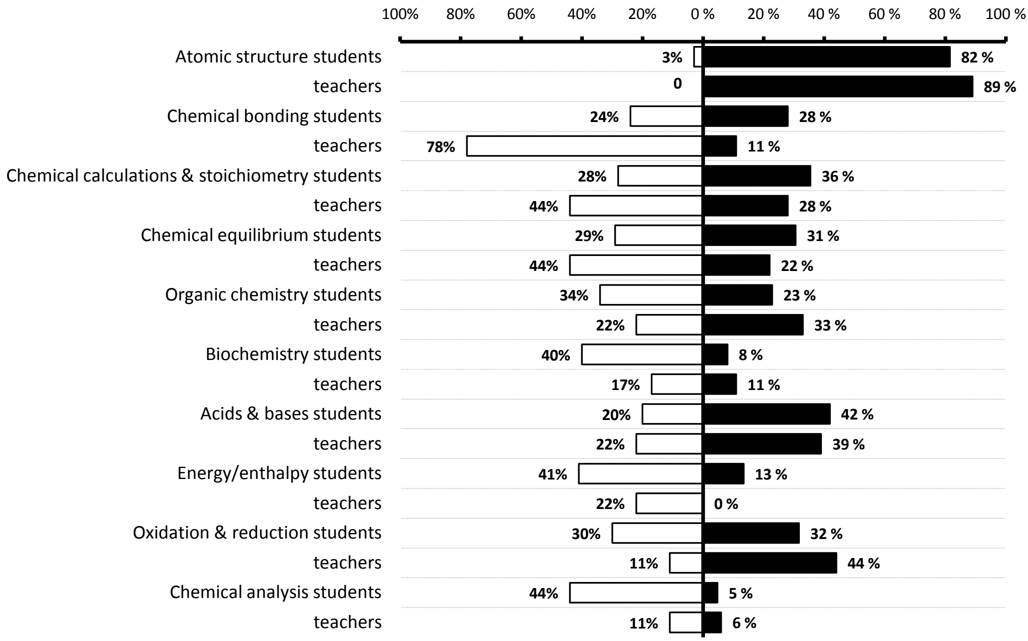

Figure 3. Students' (N_s=372) view of different areas in chemistry compared to their teachers' (N_t=18) ideas about how their students experience chemistry. Areas identified as easy are marked black and difficult are marked white.

mistry' and 'chemical bonding' since these areas were vast and abstract. They were clear about what their students found easy (i.e. 'atomic structure') because of the aforementioned simple and clear rules, but were not as aware of the students' difficulties. The students' view of chemistry areas compared to their teachers thoughts about their students' opinions are presented in figure 3. The teachers thought students found 'chemical bonding' hard; an area students in fact considered quite easy. In addition, the teachers were not aware of areas students found difficult ('biochemistry' and 'chemical analysis').

Students' view of their chemistry lessons

Working methods in chemistry classrooms were examined in the student questionnaire to try to get a picture of their chemistry lessons. The results reveal very teacher-centred lessons. Almost all students (93%) report their teacher talking and asking questions in every lesson. But students are in general satisfied with this; 85% think they learn chemistry well or very well when the teacher conducts lessons in this way. The same percentage of students think they learn chemistry well or very well when discussing chemistry both with classmates and the teacher, but this working method is used more seldom. Laboratory work is on average done once every two weeks, and 76% of the students think they learn chemistry well or very well by doing experimental work. The method students found least effective was to work on their own, but still 67% thought they learn chemistry well or very well when they work with assignments individually.

Finally, both students and their teachers were requested to make suggestions on how to make chemistry more meaningful and interesting, and answers were given without any response options. More than 65% (N_s=243) of the students and all of the 18 teachers responded to this question. Both groups gave the same recommendations; first of all, they wanted more laboratory and practical work, and secondly, both students and teachers suggested that chemistry education should be more closely connected to everyday life situations. Many students also emphasized the importance of teacher's competence and teachers stated a need for more classroom time.

Discussion

Atomic structure is easy

Atomic structure is one of the most scrutinized chemistry concepts, often identified as a threshold concept fundamental for mastering further understanding (de Jong & Taber, 2007; Francisco, Nakhleh, Nurrenbern, & Miller, 2002; Niaz, Aguilera, Maza, & Liendo, 2002; Park & Light, 2009). Therefore, it is remarkably that 82% of the students found 'atomic structure' easy to understand. Their teachers were fully aware of their students' apprehension and mentioned distinct rules as an explanation for this student view. According to the Swedish ROSE-study, teachers' are still selecting the area as the most important to teach even though students in this study find it easy (Oscarsson, Jidesjö, Karlsson, & Strömdahl, 2009).

Park and Light (2009) have studied the concept of atomic structure and maintain that one problem with previous research has been in focusing on students' difficulties, while not providing advice to teachers how to proceed and solve these difficulties. de Jong and Taber (2007) have discussed recurrent conceptual difficulties that students have regarding atomic structure, both the shell model and the orbital model. One possible explanation for this contradictory result, that the students find the area easy, could be that Swedish upper secondary students seldom study the orbital model. The textbooks used by the students in this study do not treat the orbital model at any length, in one it is just mentioned in a footnote, possibly not even read by the students (Lüning et al., 2009). In this way, many students might not have heard of more than the shell model, which is considered easier to understand. Atomic theory is in the curriculum presented in a descriptive manner, something van Aalsvoort (2004b) associates with chemistry education's connection to logical positivism. Logical positivism influences chemistry education and causes, according to van Aalsvoort, chemistry´s lack of relevance. Niaz et al. (2002) claim problems with the focus of factual knowledge and show that students need to think, argue, reflect and discuss the content to develop understanding of the atomic structure. Of course, no conclusions can be drawn from this questionnaire about how teachers have presented the area of atomic structure, but Nelson (2006) and van Aalsvoort (2004b) note the textbooks' apparent influences on teaching.

There might also be a problem for students with the concept of models in general, since it is not always obvious that the description of atomic structure is a model. Drechsler (2007) points out this clarity problem: models are often presented in an introductory chapter of a textbook and thereafter students are considered to "know about" and use models. Even though teachers are aware of this problem, they do not know how to relate to different models in a teaching situation. The importance of competent teachers emphasized by Osborne and Dillon (2008) and Risch (2010) must not be neglected, especially in teacher education.

Atomic structure is interesting

Atomic structure is apprehended easy by these students, as well as interesting. The area is stated third most interesting after biochemistry and organic chemistry. Students finding atomic structure interesting contradicts Swedish results from the ROSE-study where 'atoms and molecules' are presented as one of the most uninteresting parts in science (Jidesjö et al., 2009). One explanation might be that the ROSE-study is undertaken with 15-year-olds in secondary school and this study is focusing on older students at the Natural Science Programme. Since atomic structure is one of the first areas dealt with in the chemistry course and the atom is a concept in constant use throughout chemistry, students probably understand its significance.

Biochemistry is interesting and difficult

It is also notable that one area in chemistry is very interesting but at the same time difficult to learn; biochemistry. Biochemistry has many connections to the human body and health, very interesting topics for many students (Jidesjö et al., 2009; Schreiner, 2006). On the other hand, biochemistry is often considered to be a broad area with high level of detail, where much text must be read and only a few general rules are to follow. The teachers in this study agree and claim biochemistry to be a comprehensive and abstract area. Another problem in biochemistry might also be modelling and the shift between macro, sub-micro and representational/symbolic levels. Chemical phenomena are often presented in textbooks at the symbolic level, although they are explained at the, not observable, sub-micro level. Students have problems linking and relating these macro-micro-levels, and therefore Meijer, Bulte and Pilot (2009) have suggested new levels in between; the meso levels. The aim is to help students understand the relation between macroscopic phenomena and microscopic representations by using intermediate meso levels. Meijer, Bulte and Pilot have inquired into student's capacity to see structure-property-relationships in organic and biochemistry, and studying subjects related to everyday life such as gluten-free bread and bulletproof vests. They illustrate students' problems with the scale, ranging from 10^{-1} m (macro) to 10^{-8} m (micro) in the discussion of gluten-free bread.

It is important, however, to be aware of the restrictions in drawing conclusions from a questionnaire result and to bear in mind that students in this study only gave responses to the areas as headings; their understanding has not been examined. It is not possible to know how students and teachers interpreted the questions and headings, nor is it feasible to measure individual students' level of difficulty or interest compared to each other. In spite of this, the results can pave the way for subsequent qualitative studies where students' opinions of and knowledge in chemistry can be investigated.

The working methods make students satisfied

When students were asked about working methods, they seemed quite satisfied with the situation. Chemistry lessons are often teacher-centred with a teacher talking or discussing with students. As earlier mentioned, even with the method least appreciated by students, i.e. when students work on their own, 67% of the students still think they learn chemistry well. Teacher-centred methods have been studied in relation to the teachers' educational beliefs, for instance general beliefs about education, the nature of the subject and curriculum goals (van Driel, Bulte, & Verloop, 2007). Since teachers differ in their beliefs, van Driel, Bulte and Verloop suggest organizations of regional networks to support teachers who want to diversify the approaches in their teaching. However, since students in this study seem satisfied with the working methods, perhaps other changes in chemistry education are more relevant.

Practical work, laboratory work and demonstrations are regarded as fundamental working methods, something mentioned by both students and teachers in giving examples of how to enhance interest and motivation for further study of chemistry. The importance of laboratory work in science has been studied intensely within science education for many years. There have, since the late 1970s, been discussions about what students actually learn from laboratory work. Hofstein and Lunetta (2004) argue that laboratory work is an essential part of inquiry-based learning, and they claim laboratory activities based on inquiry can give students opportunities to learn and develop concepts and frameworks of concepts. Students also show improved attitudes and interest in science due to laboratory work. On the other hand, students often have problems understanding general purposes for their laboratory work and seldom use higher-level cognitive skills, since laboratory guides often follows a "cookbook" approach (Hofstein & Lunetta, 2004; van Aalsvoort, 2004b). Unfortunately, it seems as though laboratory work has been reduced in Swedish schools, possible reasons might be reduced resources, legislation about required risk assessment for laboratory work, and increased restrictions on the use of chemicals. Teachers often wish to do more practical work, but blame lack of time and money for the reduced amount of laboratory time.

Everyday life makes chemistry more meaningful

The connection to everyday life is regarded as crucial in making chemistry more meaningful, something studied in research projects on, for instance, context-based chemistry and scientific literacy courses like *Twenty First Century Science* (Bennett & Lubben, 2006; Millar, 2006). de Jong and Taber (2007) emphasize the use of relevant and meaningful contexts to make the chemistry curriculum less isolated from the students' real world. Relevance is often used as a determinant of what is interesting to students, and van Aalsvoort (2004a) presents four different meanings of the conception; relevance can be connected to personal, professional, social and personal/social spheres. Aikenhead (2006) shows that teachers unfortunately tend to prefer abstract decontextualized 'pure science' and therefore marginalize student-focused perspectives related to everyday life. Teachers often think it is a good idea to teach chemistry from an everyday perspective, but they can give many reasons not to implement such a curriculum in their own classroom (Aikenhead, 2006). First of all, they are used to specific disciplines from their own university programs during teacher education and are therefore loyal to the academic science community. Everyday perspectives require interdisciplinary thinking, something teachers seldom have practiced. Teachers also assert a lack of available classroom materials but when teaching materials are available, other reasons are given. Teachers fear losing control over the class, feel insecure about their role in the classroom and find it difficult to assess students' results (Aikenhead, 2006).

Conclusion

The role of secondary school science is often discussed with a dichotomous starting point, 'science for everyone' or 'science for the future scientist' (Millar, 2006). It is essential for these to coexist since there is a need for both future scientists as well as a well-educated public. Often there has been focus on involving everyday life in chemistry courses aimed for the public, but even students in this study, who have chosen an upper secondary school programme including elective science courses, and by this choice are possible future scientists, think it is fundamental for the school subject chemistry to be related to everyday life. These students seem quite satisfied with their chemistry courses, even though they have some suggestions for improvements (e.g. more laboratory work and connections to everyday life). Since there is a decrease in university-level chemistry students, it is important to listen to the views of these students, and their experiences are worth consideration when developing new chemistry courses and undertaking research in science education. Perhaps these satisfied students will continue their chemistry studies at university level?

From van Aalsvoort (2004a; 2004b), we concur in the importance of treating chemistry subject content as something more than factual knowledge. Students need to discuss and argue their chemistry subject knowledge with their teachers to make sure that they can go beyond basic knowledge and develop chemistry understanding. One major issue is to make sure students' awareness of the role of models within chemistry education. The significance of competent teachers cannot be emphasized enough, since they are fundamental for successful educational systems (Risch, 2010). Implications can be drawn from our study as a base for future combined qualitative and quantitative studies on context-based chemistry related to everyday life. Since questionnaires make it impossible to study the activity in the classroom, no conclusions can be drawn from this study on how teachers teach, and therefore we cannot conclude if there in fact have been connections to everyday life. It is fundamental to understand how this connection to everyday life can make students more interested in chemistry and thereby hopefully more knowledgeable. Context-based chemistry might be one way to help solving the chemistry crisis and be conducive to more chemistry students in tertiary education.

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Appendix A

Questionnaire to students in upper secondary school concerning chemistry

School and town: ____

Program: ____

Sex	☐ Girl	☐ Boy	
Grade	☐ Grade 10	☐ Grade 11	☐ Grade 12
Chemistry courses completed	☐ Course A	☐ Course B	☐ Extension course

Which subjects do you like best in school? Give examples of maximum 4:

____

Which chemistry book do you use in your class? Write the name of the publisher:

____

Which of the following do you think is easiest in chemistry? Mark the 3 easiest.

- ☐ Atomic structure
- ☐ Chemical bonding
- ☐ Chemical calculations & stoichiometry
- ☐ Chemical equilibrium
- ☐ Organic chemistry
- ☐ Biochemistry
- ☐ Acids & bases
- ☐ Energy/enthalpy
- ☐ Oxidation & reduction
- ☐ Chemical analysis

Which of the following do you think is most difficult in chemistry? Mark the 3 most difficult.

- ☐ Atomic structure
- ☐ Chemical bonding
- ☐ Chemical calculations & stoichiometry
- ☐ Chemical equilibrium
- ☐ Organic chemistry
- ☐ Biochemistry
- ☐ Acids & bases
- ☐ Energy/enthalpy
- ☐ Oxidation & reduction
- ☐ Chemical analysis

Which of the following do you think is the most interesting in chemistry? Mark the 3 most interesting.

- ☐ Atomic structure
- ☐ Chemical bonding
- ☐ Chemical calculations & stoichiometry
- ☐ Chemical equilibrium
- ☐ Organic chemistry
- ☐ Biochemistry
- ☐ Acids & bases
- ☐ Energy/enthalpy
- ☐ Oxidation & reduction
- ☐ Chemical analysis

Which of the following do you think is the least interesting in chemistry? Mark the 3 least interesting.

- ☐ Atomic structure
- ☐ Chemical bonding
- ☐ Chemical calculations & stoichiometry
- ☐ Chemical equilibrium
- ☐ Organic chemistry
- ☐ Biochemistry
- ☐ Acids & bases
- ☐ Energy/enthalpy
- ☐ Oxidation & reduction
- ☐ Chemical analysis

How often do you use the following working methods at chemistry lessons?

	At every lesson	Once a week	Once a month	Never
The teacher talks and asks questions	☐	☐	☐	☐
The students work alone	☐	☐	☐	☐
The teacher and the students discuss together	☐	☐	☐	☐
The students do laboratory work	☐	☐	☐	☐
The teacher demonstrates something	☐	☐	☐	☐

How do you experience that you learn chemistry out of the following methods of working?

	Very good	Good	Neither good nor bad	Bad
The teacher talks and asks questions	☐	☐	☐	☐
The students work alone	☐	☐	☐	☐
The teacher and the students discuss together	☐	☐	☐	☐
The students do laboratory work	☐	☐	☐	☐
The teacher demonstrates something	☐	☐	☐	☐

What do YOU think can be done to make the chemistry subject more interesting and meaningful for students in upper secondary school?

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Appendix B

Questionnaire to teachers in upper secondary school concerning chemistry

Sex ☐ Woman ☐ Man

School and town: ____

How many years have you been working as a chemistry teacher? ___________________________

Do you teach another school subject? If so, which? ____

Which chemistry book do you use in your class? Write the name of the publisher:

____

Which of the following do you think is easiest to teach in chemistry? Mark the 3 easiest.

☐ Atomic structure

☐ Chemical bonding

☐ Chemical calculations & stoichiometry

☐ Chemical equilibrium

☐ Organic chemistry

☐ Biochemistry

☐ Acids & bases

☐ Energy/enthalpy

☐ Oxidation & reduction

☐ Chemical analysis

Why, do you think?

____

Which of the following do you think is most difficult to teach in chemistry? Mark the 3 easiest.

- ☐ Atomic structure
- ☐ Chemical bonding
- ☐ Chemical calculations & stoichiometry
- ☐ Chemical equilibrium
- ☐ Organic chemistry
- ☐ Biochemistry
- ☐ Acids & bases
- ☐ Energy/enthalpy
- ☐ Oxidation & reduction
- ☐ Chemical analysis

Why, do you think?

____

Which of the following do you think is easiest for the students? Mark the 3 easiest.

- ☐ Atomic structure
- ☐ Chemical bonding
- ☐ Chemical calculations & stoichiometry
- ☐ Chemical equilibrium
- ☐ Organic chemistry
- ☐ Biochemistry
- ☐ Acids & bases
- ☐ Energy/enthalpy
- ☐ Oxidation & reduction
- ☐ Chemical analysis

Which of the following do you think is the most difficult for the students? Mark the 3 most difficult.

- ☐ Atomic structure
- ☐ Chemical bonding
- ☐ Chemical calculations & stoichiometry

- ☐ Chemical equilibrium
- ☐ Organic chemistry
- ☐ Biochemistry
- ☐ Acids & bases
- ☐ Energy/enthalpy
- ☐ Oxidation & reduction
- ☐ Chemical analysis

What do YOU think can be done to make the chemistry subject more interesting and meaningful for students in upper secondary school?

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