Connecting the chemistry curriculum with work- and everyday life

Important aspects for the development of a material supporting chemistry teachers in Swedish upper secondary school

Master's thesis in Learning and Leadership

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CHALMERS UNIVERSITY OF TECHNOLOGY

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ABSTRACT

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Motivation and context are two important keys to positive learning outcomes. This master's thesis aims to develop the prerequisites for a material that can help chemistry teachers in Swedish upper secondary school to connect the curriculum with work- and everyday life. The purpose of the material would be to make the theoretical content of the courses more relevant and engaging to the students and thereby helping the teachers create a motivational learning environment. The research questions concern the need for this kind of material, existing material and the potential format, platform, and content of such a material. The study consisted of two parts. First, a questionnaire was sent out to Swedish upper secondary chemistry teachers. Secondly, a prototype of the material was developed which 11 chemistry teachers tested for five weeks. This user test was then evaluated using semi-structured interviews. The results suggests that there is no existing material, that the teachers know of, that fills the purpose of making the connection between the curriculum and work- and everyday life and that there is a need amongst chemistry teachers for such a material. This study also suggests that the material should be web-based in order to be able to include features such as animations, videos, and easy navigation. One possible platform for this material is suggested to be *Kemilärarnas resurscentrum* (KRC). Regarding content, the results show that useful categories include "Everyday phenomena", "Everyday products", "Historical events", "News" and "Interviews with professionals". Further results regarding content concerns sustainable development, level of detail, level of concretion in the connection to the curriculum and a number of other aspects. The conclusion consists of a list of recommendations for the development of a material making the connection between the chemistry curriculum in Swedish upper secondary school and work- and everyday life.

Key words: Curriculum, Chemistry, Motivation, Scientific literacy, Vision II, Upper secondary school, Everyday phenomena, Everyday products, Context-Based Learning, Science-Technology-Society,

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1. INTRODUCTION

This report covers a master's thesis that was carried out between January to June, year 2021. The thesis was written by two teacher students at Chalmers University of Technology as part of the master's program Learning and leadership. This initial chapter will describe the background of the thesis and specify the aim, objectives, scope, and limitations of the study, as well as the outline of this report.

1.1. Background

In *Skollagen* [the Swedish Education act] it is stated that every child is to be given the guidance and stimuli they need to reach as far as possible in their learning and personal development (SFS 2010:800), but how is this efficiently accomplished? One considerable aspect of learning and personal development is that of motivation and another aspect is the strive towards scientific literacy.

In general, motivation is what enables a person to reach a goal (Eilks et.al., 2013) and according to Vallerand et.al. (1992) motivation is one of the most important psychological aspects in education since "motivation is related to various outcomes such as curiosity, persistence, learning and performance" (Vallerand et.al., 1992, p. 1004). There are many different types of motivation, and therefore many aspects of how motivation is achieved. Deci et.al. (1991) describes how intrinsic motivation is the most efficient when it comes to both learning, conceptual understanding, and personal growth. Eilks et.al. (2013) presents various models for enhancing intrinsic motivation in the classroom and what that they all have in common is relevance and perceived value of the taught subject. One example of such a model is the *Model of Motivational Learning Environment* which suggests that subject relevance and value can lead to both higher performance and greater satisfaction for the student (Eilks et.al., 2013). Tanner (2010) also suggests that one of the most important prerequisites of learning is interest in what is being learned and that the learner finds the material useful.

The other aspect, scientific literacy, which deals with questions about what it means to understand science, has been reshaped during the last 60 years. Using the concepts established by Roberts (2007a), there has been a shift from the more traditional Vision I of scientific literacy, which concerns the very core of science itself by looking inward, to Vision II, which views scientific literacy as the ability to understand science in its cultural, societal, and everyday context. This shift has paved the way for new approaches to science and technology education such as *context-based learning* (CBL) (King, 2012; Sevian, 2018) and the *Science-Technology-Society* (STS) approach (Ainkenhead, 1994; Bennett et.al, 2006), which both place a heavy emphasis on the connection between traditional school science and the contexts in which they are found, such as work- and everyday life. This connection is also found in the subject curricula of the nature science courses where it is stated that one aim of the teaching is for students to develop an understanding of the impact of science for individual- and societal life (Skolverket, 2011a, 2011b, 2011c).

The teachers are the ones responsible for creating an environment that support learning in school. This is anchored in the curriculum for the Swedish upper secondary school which states that teachers are to teach in a way which makes the students find the material meaningful and provides overview and context (SKOLFS 2011:144). However, in Sweden almost half of all teachers in upper secondary education experience stress in their work, which means that every resource that can reduce the workload for teachers is welcome (OECD, 2020). Among the same group of teachers 90% reported that they use online resources when preparing classes (Skolverket, 2016). When Swedish upper secondary chemistry teachers were asked what online resources they used for preparing classes, no source with the clear purpose of making a connection between the curriculum and work- and everyday life was reported (Lundberg & Widén, 2017). Moreover, in conversations with teachers, the authors of this study have perceived a lack of such resources, resulting in teachers struggling to find the time to make engaging material fit within the boundaries of the curriculum. This also seems to result in teachers having to create or find their own material for engaging their students, assuming there is time to do so. Hence, there appears to be a demand for a material that makes the connection between the curriculum and work- and everyday life.

1.2. Aim

The aim of this study is to develop the prerequisites for a material connecting the curriculum for Swedish upper secondary school chemistry with work- and everyday life. The purpose of this material is to help teachers in their task to motivate and engage their students, thereby facilitating learning, and provide context in order to strive for scientific literacy. The goal is that the prerequisites will be sufficiently detailed so that someone with the capacity to develop this material in full can use the results of this study to help the material fulfil its purpose.

1.3. Objectives

In this study, the focus will be to answer the following question and its sub-questions.

- What aspects are of importance when developing a material of connections between the Chemistry curriculum and work- and everyday life for chemistry teachers to use in Swedish upper secondary schools?
  - To what extent do chemistry teachers experience existing material to fulfil the purpose of making the connection between the curriculum and work- and everyday life?
  - To what extent do chemistry teachers experience a need for a material making the connection between the curriculum and work- and everyday life?
  - What kind of format and platform would be suitable for a material with the purpose of making the connection between the curriculum and work- and everyday life?
  - What kind of content would chemistry teachers find useful in a new material with the purpose of making the connection between the curriculum and work- and everyday life?

1.4. Scope and limitations

The study does not intend to create a full version of the material, but a mere prototype to be tested in order to set up a few guiding statements should a person or company be interested in creating the full material. The focus of these statements is mainly to address the research questions from the teachers' point of view. That mean that a number of aspects will be overlooked, such as, for example, graphic design and the students' point of view. Moreover, the study will not investigate the possible outcomes concerning for example student results or classroom environment but rather be based on the teachers' experiences and needs during class preparation, neither will the study investigate the research questions from the students' point of view. The prototype will not contain material for an entire course but two areas of work from the course Chemistry 1 at the Swedish upper secondary school. Which areas of work that will be included in the prototype will be selected to match the course planning of the testing teachers.

1.5. Outline

This master's thesis report consists of five parts. This first part is an introduction where the present study is rooted in its context and the aim and boundaries are described. The second part outlines the theoretical framework of the study. First and foremost, it describes the two areas on which this thesis has its foundation; motivation and the Vision II of scientific literacy, but it also present what online resources already exist and are used by chemistry teachers. The third part outlines the methods that were used for the study and motivate why they were used. In the fourth part the result is presented along with a discussion, one area at the time. The fourth part ends with an evaluation of the methods used and suggestions for further research. The fifth, and last, part of the report consists of the conclusions drawn from the study.

The report also includes three appendices, which contain various documents that were used in the study and are presented in their original Swedish version. The first appendix, Appendix A, contains the survey in its entirety as the respondents saw it. Appendix B contains the outline of questions used by the interviewer at the semi-structured interviews. Appendix C contains the prototype that was sent out to the teachers who were a part of the study.

2. THEORETICAL FRAMEWORK

In the following section, the theoretical framework for this thesis is set, starting with the structure and regulatory documents for Swedish upper secondary school. The second section describes learning, and is followed by sections describing motivation, interest, and scientific literacy. The final section of the theoretical framework concerns existing materials and resources used by chemistry teachers in Swedish upper secondary school.

2.1. Structure and regulatory documents for Swedish upper secondary school

The basis for this master's thesis is set in the Swedish upper secondary school, that is grades 10 to 12, and chemistry teaching in particular. There are a number of different regulatory documents for Swedish upper secondary school that are important to understand in order to set this thesis in context. An overview of the structure and the different regulatory documents is presented in Figure 1.

In the broadest sense there is *Skollagen* [the Education act], which contains the regulations set by law, common for all school forms (SFS 2010:800). The notable exception is studies at a university, which are not regulated by the Education act. Three chapters are dedicated to the upper secondary school, which is separated from the upper secondary school for students with special needs. The first of these chapters contains general regulations of the school form and grading, regulations for institutions running schools, and regulations for educations with adjustments for students with movement related disabilities. The two following chapters contains regulations for different programs at the upper secondary school (SFS 2010:800).

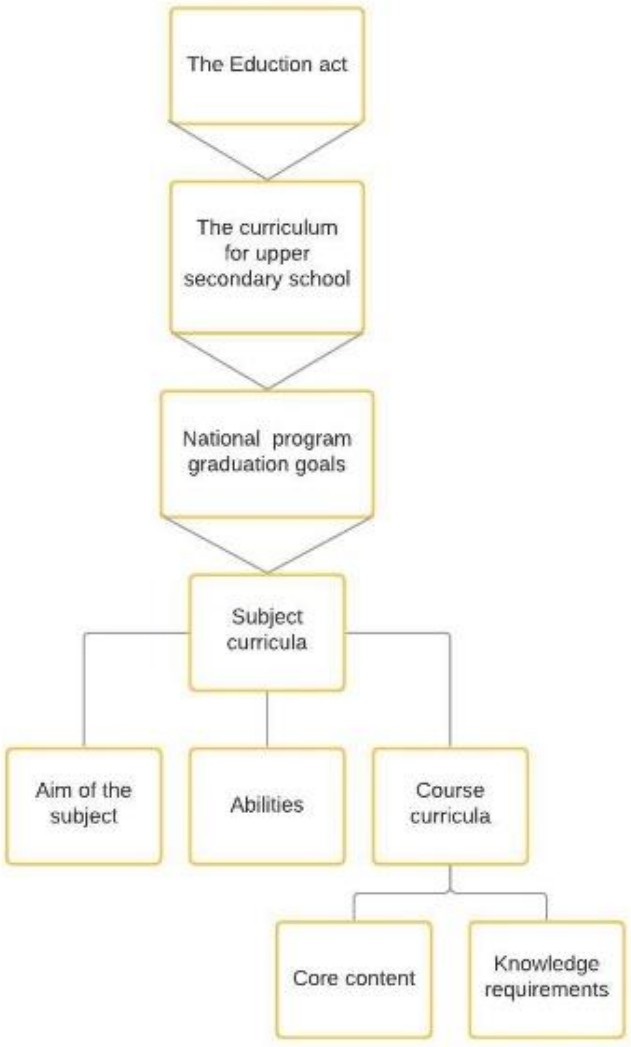

Figure 1. An overview of the different regulatory documents, and the structure between them, for the Swedish upper secondary school. (SFS 2010:800; Skolverket, 2019).

Further on, the upper secondary school is regulated by a document called *Läroplan för gymnasieskolan* [Curriculum for the upper secondary school] (SKOLFS 2011:144). This document consists of two parts. The first part concerns the general values and missions of Swedish upper secondary education. To some extent this part repeats, and refers to, what is stated in the Education Act but it is also descriptive in greater detail. For example, there is an emphasis on the inclusion of the ethical, the environmental, the international, and the historical perspectives in the school's mission (SKOLFS 2011:144). The second part of the Curriculum for the upper secondary school concerns general goals and aims of, for example, knowledge, norms and values, evaluation and grades, and the responsibilities of the principal. Among other things, it is stated that in the education, the teacher should aim to "utnyttja de kunskaper och erfarenheter av arbets- och samhällsliv som eleverna har eller skaffar sig under utbildningens gång" [use the knowledge and experience of work-, and societal life the students have, or gather during the education] and "organisera och genomföra arbete så att eleven får möjlighet till ämnesfördjupning, överblick och sammanhang" [organise and implement work so that the student has the opportunity of subject specialization, overview and context] (SKOLFS 2011:144, p. 6).

After the Curriculum for the upper secondary school, the next regulatory document contains the graduation goals for the different national programs. These describe what the contents of each program should be and what abilities the students who undergo them should have learned before graduation. For example, it is stated that *Naturvetenskapsprogrammet* [the Nature science program] is to provide "förståelse av hur naturvetenskap och samhällsutveckling ömsesidigt har påverkat och påverkar varandra" [understanding about how nature science and societal development mutually have affected and are affecting each other] (p.47) and that the program is to develop "elevernas kunskaper om sammanhang i naturen, om livets villkor, om fysikaliska fenomen och skeenden och om kemiska processer." [the students' knowledge about coherence in nature, the conditions of life, about physical phenomena and processes and about chemical processes] (Skolverket, 2011d, p. 47). The programs that offer chemistry courses are the Nature science program and *Teknikprogrammet* [the Technology program].

The next regulatory document is called *Ämnesplan* [Subject curriculum] and includes what should be considered for each of the subjects taught in Swedish upper secondary school. Every Subject curriculum consists of three parts. First there is *Ämnets syfte* [the Aim of the subject], which explains the purpose of including the subject in upper secondary education and why the subject is important. The second part is a list of *Förmågor* [Abilities] that the students should strive to develop when taking courses in the subject. The third part is *Kursplaner* [the Course curricula] for the different courses possible to take in the subject. Chemistry, for example, has two courses, Chemistry 1 and Chemistry 2 (Skolverket, 2019). In turn, the Course curriculum contains two parts. The first is a list of the different elements that should be covered in the course, called *Centralt innehåll* [Core content]. According to Skolverket (2019), the teacher is free to give different elements different amount of time in class, as long as the elements are all covered in the course. The different elements can also be combined in projects and work areas as the teacher sees fit. The second part of the Course curricula are *Kunskapskrav* [Knowledge requirements], which states what qualities the student should demonstrate in order to receive different grades (Skolverket, 2019). The teachers are to base their teaching on the Aim of the subject and the Core content while the examination and grading is to be based on the Knowledge requirements (Skolverket, 2019).

2.1.1. The Swedish National agency for education

Both the Education act, the Curriculum for Swedish upper secondary school and the National program graduation goals are documents published by the Swedish government. The Subject curricula, however, are created and published by the national agency *Skolverket* [the Swedish National agency for education], by order of the Swedish government. The Swedish National agency for education "is the central administrative authority for the public school system, publicly organised pre-schooling, school-age childcare and for adult education." (Skolverket, 2020a). In short, the tasks of the Swedish National agency for education include establishing frameworks for how the education is practised, for example by creating regulatory documents such as Subject curricula, performing statistical studies, supporting improvement work and offering teachers the possibility of in-service training (Skolverket, 2020b) Henceforth, the Swedish term *Skolverket* will be used to refer to the Swedish National agency for education, in order to communicate clearly within the Swedish context of this thesis.

2.1.2. The Chemistry curriculum

In the Aim of the subject in the Chemistry curriculum it is stated, among other things, that the teaching is to help the student develop knowledge in a number of aspects of the subject. For example, knowledge concerning "concepts, theories, models, and methods of chemistry" (Skolverket, 2011c, p. 1), different chemical processes, the significance of chemistry for "climate, environment, and the human body" (p. 1), and the application of chemistry in, for example, "new medicines, new materials and new technology" (p. 1). The Aim of the subject also have a part concerning the roles of experiments, hypotheses and scientific methodology in chemistry and science, and it is stated that the student is to develop a scientific point of view on matters of society.

The Core content in Chemistry 1 consists of the following areas: matter and chemical bonding, reactions and changes, stoichiometry, analytical chemistry, and the nature of chemistry and its working methods. The Core content of Chemistry 2 consists of the areas reaction speed and chemical equilibrium, organic chemistry, biochemistry, analytical chemistry and the nature of chemistry and its working methods. Each of the areas in both Chemistry 1 and 2 then consists of several different items describing in greater detail what should be included in each course.

Henceforth, when using the term "curriculum", what is referred to is the Chemistry curriculum, i.e., the Subject curriculum for chemistry. The Chemistry curriculum includes the Aim of the chemistry subject in Swedish upper secondary school, the Abilities, and the Core content- and Knowledge requirements for the different chemistry courses.

2.2. Deep learning and conceptual understanding

The main task of the Swedish upper secondary school is to "förmedla kunskaper och skapa förutsättningar för att eleverna ska tillägna sig och utveckla kunskaper" [mediate knowledge and create prerequisites for students to assimilate and develop knowledge] (SKOLFS 2011:144, p. 2) or, in other words, to help students learn. But what does it mean to actually learn? The Curriculum for Swedish upper secondary school elaborates the term "knowledge" to include several things, such as facts, skills, and familiarity, and that these types of knowledges need to interact (SKOLFS 2011:144). In this section, the term *learning* is

elaborated through the constructs *deep*- and *shallow learning* and *conceptual understanding*, with the aim to define what should be strived for in order to facilitate long-term learning.

To achieve deep learning, the learner has to adopt a deep approach to learning. A deep approach to learning is described by Smith and Colby (2007) as trying to understand the big picture, to focus on comprehending the concepts and the relationship between different aspects. Deep learning has been achieved when the student understands the big picture, is able to put different aspects in relation to each other, and is able to impose meaning and formulate hypotheses regarding the taught subject (Biggs & Collis, 1982; Smith & Colby, 2007). Taking a deep approach to learning was found to be related to asking oneself different, reflective questions while learning, for example, "What is the broader implication or significance of what I've learned?" (Smith & Colby, 2007, p. 205). Deep learning is often achieved when there is an intrinsic interest, i.e., when the student is genuinely interested in the subject (Smith & Colby, 2007). Smith and Colby (2007) also state that teachers are responsible for promoting deep learning in their students, for example by promoting a deep approach to learning by guiding the students in asking reflective questions while learning.

On the other side of the learning-spectra, there is surface learning, also called shallow learning. Surface learning occurs when the learner is focused on memorizing, rather than understanding, and the learning process therefore does not require reflection. The outcome of surface learning is generally that the learner has the ability to perform standard procedures but struggles to apply their knowledge in a new situation (Biggs & Collis, 1982; Smith & Colby, 2007). Deep learning, unlike surface learning, is according to Smith and Colby (2007) related to high quality learning outcomes, for example long-term learning and understanding.

To reach deep learning, one important step is to achieve conceptual understanding. Holme et.al. (2015) performed a study with approximately 1400 university- or college chemistry teachers in order to define conceptual understanding. The result was a five-part definition with the following components: *transfer*, *depth*, *predict*, *problem solving* and *translate*. Transfer is when the student can apply their knowledge to new situations. Depth means that the student can reason about chemistry concepts in more than a mere memorization fashion. Predict is when the student is able to use their knowledge to predict the behaviour of a chemical system. Problem solving is when the student can use critical thinking and solve problems concerning chemistry concepts, for example in the laboratory. The last component of the definition, translate, is when the student is able to navigate between different scales and representations (Holme et.al., 2015). This definition of conceptual understanding provides a more detailed description of what it means to achieve deep learning, and thereby a more qualitative and long-term learning.

2.3. Motivation in learning

To achieve deep learning, Deci et.al (1991) states that the learner must be motivated. In fact, this is true for any "goal-directed behaviour" (Heckhausen, 1991, s. 1). Bolte et.al. (2013) describes motivation as "the driving force by which humans achieve their goals" (p. 68). Deci and Ryan (2000) define motivation as something that moves a person to do something and Koballa and Glynn (2007) further defines motivation in learning science as "an internal state that arouses, directs, and sustains students' behaviour" (p. 85). A person that feels no drive to

do anything is considered unmotivated, or *amotivated* (Deci & Ryan, 2000). Vallerand et.al (1992) considers motivation to be of great importance in education as it promotes outcomes related to lifelong learning, which is one of the values which Swedish upper secondary schools strives to mediate to its students (SKOLFS 2011:144). However, the effect differs between various types of motivation, and also between different people and different situations (Bolte et.al., 2013). Deci and Ryan (2000) describe how people can have both different levels of motivation, i.e., how strong their motivation is, and different types of motivation. There is a distinction between two different categories of motivation, *extrinsic motivation*, and *intrinsic motivation*. The latter has a stronger connection to positive educational outcomes such as deep learning and creativity (Deci & Ryan, 2000).

2.3.1. Extrinsic motivation

Extrinsic motivation is when the activity is performed as means to an end (Deci & Ryan, 2020; Locke & Schattke, 2019; Vallerand et.al, 1992). When extrinsically motivated, the enjoyment does not come from the activity itself but rather from a future value, gained by performing the activity (Locke & Schattke, 2019). This type of motivation can be very effective, for example when setting goals. Based on Deci and Ryans (1991) *self-determination theory* (SDT), Vallerand et.al. (1992) describes three categories of extrinsic motivation distinguished by their level of self-determination and internalization. The first is called *external regulation* and is when the motivation comes from external promises, such material rewards, or threats. The second, called *introjected regulation*, is a bit more internalized, but still not self-determined. Vallerand et.al (1992) uses the example of a student studying before exams because "that is what good students are supposed to do." (p. 1006) to explain introjected regulation. The third, called *identification*, is both internalized and self-determined, for example as in a person doing something because they find it important. This third type is volitional but still not necessarily intrinsic since the person might not find the activity in itself enjoyable. Deci and Ryan (2020) have since added a fourth type of extrinsic motivation, *integration*, which is internalized to the point where the individual fully identifies with the behaviour or activity so that it corresponds with the persons core values.

2.3.2. Intrinsic motivation

Intrinsic motivation is usually described as motivation to do something for the inherent satisfaction or enjoyment of the activity itself, even if there is no promise of rewards or threats of punishment (Lepper & Henderlong, 2000; Vallerand et.al., 1992). Vallerand et.al. (1992) further define three categories of intrinsic motivation from motivation literature. There is *intrinsic motivation-to know*, which is the motivation that stems from the feeling of pleasure and satisfaction from learning, exploring, and trying to understand something new. The second is *intrinsic motivation-toward accomplishment*, which is the "fact of engaging in an activity for the pleasure and satisfaction experienced when one attempts to accomplish or create something." (p. 1005). The third is *intrinsic motivation-to experience stimulation*, which is the motivation to perform an activity for the "stimulation sensations […] derived from one's engagement in the activity." (p. 1006).

2.3.3. Elaborating motivation

In their paper *Intrinsic and Extrinsic Motivation: Time for Expansion and Clarification*, Locke and Schattke (2019) suggest that, beside extrinsic and intrinsic motivation, there is a third, independent type of motivation called *achievement motivation*. They argue that, rather than including achievement in intrinsic motivation as do Vallerand et.al (1992), achievement motivation is distinguishable and stems from the satisfaction of competing with a standard, accomplishing something, or improving (Locke & Schattke, 2019). According to Locke and Schattke (2019), intrinsic motivation is limited to the enjoyment of doing an activity, since it is possible to be intrinsically motivated to do something without being good at it or improving at it.

Locke and Schattke (2019) further suggest that the best type of motivation is a combination of different types of motivation. Deci and Ryan (2000) point out that not all activities are intrinsically motivating for all people. The activity needs to be inherently interesting for the particular individual. If not, they also argue that a combination of motivation types is needed (Deci & Ryan, 2000).

It is important to point out that it is rarely possible to distinguish one, and only one type of motivation behind a behaviour. Often a person is motivated by different types simultaneously (Deci & Ryan, 2020). There is also not a "wrong" or "right" type of motivation in the way that intrinsic motivation is always stronger and better than extrinsic motivation. Even if intrinsic motivation has a stronger connection with positive learning outcomes, it is not possible to generate intrinsic interest from all students in all subjects and, therefore, it is important to work with both intrinsic and extrinsic motivation in an educational setting (Deci & Ryan, 2000; Deci et.al., 1991; Vallerand et.al., 1992). However, Deci and Ryan (2020) state that, in educational settings, the most effective motivation when it comes to high student engagement and high-quality learning outcomes, is motivation with a high level of self-determination. Therefore, when working with extrinsic motivation, one should strive for introjected regulation or identification, as they have the highest level of self-determination amongst the different types of extrinsic motivation (Deci & Ryan, 2020).

2.4. Interest, attitudes, and relevance

When talking about motivation, there are several other concepts that usually get brought up. One of those concepts is *interest*. There is a considerable overlap between motivation, intrinsic motivation in particular, and interest (Bolte et.al., 2013). Deci and Ryan (2000), for example, state that for intrinsic motivation to occur, the activity has to be perceived as interesting. While motivation is described as a driving force of behaviour, Bolte et al. (2013) conceptualize interest as "a specific relationship between an individual and a topic, an object, or an activity, which is characterised by positive emotional experiences and feelings of personal relevance." (p. 70). Interest is typically divided into three categories. The first type is *situational interest*, which occur in a particular situation and is short-termed, for example triggered by an exciting activity. The second is called *individual interest* and is a more long-term and stable type of interest. The third is called *topic interest*, which sometimes is considered a part of individual interest, and is considered a lasting interest for a certain topic, for example a school subject (Bolte et.al., 2013; Nieswandt, 2007). According to Nieswandt (2007), individual interest

influences "students' selective attention, effort, and willingness to persevere in a task, and their activation and acquisition of knowledge" (p. 910). Bolte et.al. (2013) state that reoccurring situational interest can lead to individual interest, and therefore teachers should strive to make their lessons interesting for the students. Furthermore, interest is related to positive emotions, and is sustained as long as those positive emotions dominates over negative ones, such as frustration (Bolte et.al., 2013; Koballa & Glynn, 2007). If there are reoccurring negative factors, for example boring lessons or if the level of difficulty is too high or too low, interest will fade (Bolte et.al., 2013).

Apart from being strongly related to intrinsic motivation (Koballa & Glynn, 2007), interest is also important for creating conceptual understanding. Bolte et.al. (2013) describe how interest helps expand cognitive structures, meaning that when a person is interested in a subject, he or she wants to learn more and therefore readies their cognitive structures to do so. Nieswandt (2007) further shows that situational interest can have positive, short-term effects on conceptual understanding and help create a positive self-concept, which also have positive effects on conceptual understanding. Yet another reason why interest is important in the classroom is given by Vispoel and Austin (1995), who in their study let junior high school students rate different attributions' effect on student achievement. Vispoel and Austin (1995) showed in this study that the student rated "lack of interest" as the most influential factor of failure and "interest" as the second most influential factor for success, thus showing the importance of stimulating interest in the classroom.

Another concept closely related to motivation and interest is *attitudes*. The concept of attitudes is described as a person's general predisposition for something, a positive or negative feeling towards something (Bolte et.al., 2013; Koballa & Glynn, 2007; Nieswandt, 2007). For example, a positive attitude towards chemistry could be expressed as "I love chemistry", while a negative attitude could be, for example, "Chemistry is boring". Koballa and Glynn (2007) state that attitudes influence motivation, which in turn is important for positive learning outcomes.

How does one create a classroom environment which stimulates motivation, interest, and positive attitudes? Bolte et.al. (2013) describes a number of models concerning the development of these factors, for example *The 6 C's Model of Motivation*, *The Model of Motivational Design* and *The Motivational Learning Environment Model* (The MoLE Model). One thing they have in common is the importance of subject *relevance*. In the MoLE Model, subject relevance means that the topic has to be made relevant "in regard to [the students'] everyday life" (Bolte et.al, 2013, p. 76). The Model of Motivational Design refers to relevance as making it "clear how the topic concerns the learner currently and in the future […]" (Bolte et.al., 2013, p. 82) and The 6 C's Model describes it as constructing meaning and value to the students (Bolte et.al., 2013).

Bolte et.al. (2013) conclude their discussion of different models for motivation with a number of general strategies to be used by chemistry teachers in order to stimulate motivation. One of them is to "combine the topics with contexts which are relevant from students' view" (p. 84). The other strategies mentioned are to make sure the content is level with the students' abilities and to vary the learning environment so that students can participate in multiple different ways (Bolte et.al., 2013).

2.5. Scientific literacy

In the Curriculum for upper secondary school (SKOLFS 2011:144), it is outlined that the school cannot on its own provide all the knowledge the students will need in their work and everyday life. Thus, it is important that the school educates students on how to approach and understand science by themselves. Such abilities are often gathered under the term *scientific literacy*. However, to define what scientific literacy is at its core and what qualities the scientific literate person possesses appears to be a difficult endeavour since definitions vary greatly between researchers. According to the Organisation for Economic Co-operation and Development (OECD, 2018), scientific literacy is defined as "the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen" (p. 75) and the scientific literate person as someone who can "explain phenomena scientifically", "evaluate and design scientific enquiry" and "interpret data and evidence scientifically" (p. 75). Another definition is offered by the United States National Research Council (NRC, 1996), which defines scientific literacy as "the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity" and the scientific literate person as someone who can "ask, find, or determine answers to questions derived from curiosity about everyday experiences." (p. 22).

In order to deal with various definitions of scientific literacy, Roberts (2007a), in his chapter on scientific literacy in *Handbook of Research on Science Education*, proposes a spectrum between two visions of scientific literacy. These visions are not mere definitions, but broader categories. The visions on opposite sides of the spectrum he calls *Vision I* and *Vision II*. Vision I emphasises aspects which concerns the very core of science itself by looking inward, rather than on matters that only relate to science. In a sense Vision I is a more traditional view of scientific literacy, achieved by understanding science as an isolated subject. In contrast, Vision II is one which emphasises "the character of situations with a scientific component, situations that students are likely to encounter as citizens" (Roberts, 2007a, p. 730). Thus, Vision II, views scientific literacy as the ability to understand science in its cultural, societal, and everyday context.

Using these categories, the NRC definition above arguably leans somewhat more towards the Vision II than the OECD (2018) definition. This since the NRC (1996) definition on every level relates the scientific understanding to cultural matters and everyday life, thus providing a context. The OECD (2018) definition notes the value of science for the "reflective citizen", in accordance with Vision II, however, emphasises the purely scientific components such as the "scientific enquiry" and the ability to "interpret data and evidence scientifically", which are rather Vision I qualities.

Education reforms have often been propelled by some national education crisis, such as alarming results in worldwide education assessments. This can, for example, be seen in relation to international evaluations of education, such as Germany's response to their scoring in the PISA (Programme for International Student Assessment) study and in Canada, in relation to their poor results in the TIMSS (Trends In International Mathematics And Science Study) test, both around the shift of the millennia (Roth & Barton, 2004). In the United States the launch of Sputnik in 1957 by their cold war rival, trigged an extensive education debate which brought up questions of scientific literacy to the awareness of the general public (Hetherington, 1982). However, curricula developed in the 1950/60 still had a strong Vision I of scientific literacy. It

was first in the epoque of the "1980 and Beyond" that Vision II was noticeable in the broader debate. Even though Vision I resurfaced in the mid-1980s, since the 1990s there has been extensive research in various aspects of Vision II, making Vision II a highly relevant view on scientific literacy (Roberts, 2007b).

2.5.1. Vision II practised

Strongly rooted in the Vision II of scientific literacy are the notions of *context-based learning* (CBL) (King, 2012; Sevian, 2018) and the *Science-Technology-Society* (STS) approach (Ainkenhead, 1994; Bennett et.al, 2006). In this section these concepts will be defined and explored.

Defining Context-Based Learning (CBL) and Science-Technology-Society (STS)

Within the field of context-based education several definitions for "context-based" occur. Bennett et.al (2006) notes that "context-based approaches are approaches adopted in science teaching where contexts and applications of science are used as the *starting point* [emphasis added] for the development of scientific ideas.". Another definition is offered by King (2012) who means that "a context-based approach is when the 'context' or 'application of the chemistry to a real-world situation' is *central* [emphasis added] to the teaching of the chemistry." (p. 53). This definition does not require the application to be the starting point as far as it is "central", making it a broader definition. On the other hand, Gilbert (2006) offers a more strict and in-depth definition of CBL, drawing on research that lists several attributes of a context in the pedagogical sense. These attributes are, for example, that it sets a spatial and temporal framework, and that field-specific language is used to understand the context. Moreover, Gilbert (2006) goes back to the Latin word for "context" to argue that a "context" is something that "provide[s] a structural meaning for something new that is set within a broader perspective" (p. 960).

STS appears to have a more established definition than "context-based", provided by Aikenhead (1994). This definition sees STS as approaches that "emphasise links between science, technology and society by means of emphasising one or more of the following:

- a technological artefact,
- process or expertise;
- the interactions between technology and society;
- a societal issue related to science or technology;
- social science content that sheds light on a societal issue related to science and technology;
- a philosophical, historical, or social issue within the scientific or technological community." (p. 52-53)

Thus, STS is arguably a broader term than CBL. However, despite separate definitions, STS and CBL share significant overlap (King, 2009) and are at times used interchangeably in research (Bennett et.al, 2006. King, 2012). It has even been suggested that "STS" is the preferred word in North America and that "CBL" is a more European phrase (Bennett et.al, 2006). King (2012) notes that a review of context-based approaches includes STS, among other methods. Therefore, even if STS is the broader term according to the definitions, CBL or "context-based approaches" appears to be the umbrella term in many cases.

The effects of context-based/STS-approaches in chemistry education.

Gilbert (2006) presents five challenges of conventional chemistry curricula, that is curricula that are non-context-based and non-STS: (i) content overload, (ii) lack of connections between facts, (iii) lack of transfer, (iv) lack of relevance and (v) inadequate emphasis. In a study by Pilot and Bulte (2007), five of the most significant context-based chemistry curricula were evaluated in relation to Gilberts (2006) five challenges. In relation to the first challenge, all curricula contexts were chosen to avoid overload. According to Pilot and Bulte (2007) four of the five curricula selected content which allowed students to build a cognitive map of the subject chemistry, meeting challenge (ii). The third challenge was not met by any of the curricula. In relation to conventional curricula the context-based curricula did a significantly better job at providing relevance (challenge (iv)). The same goes for the fifth challenge, where context-based curricula made choices to broaden the view of scientific literacy, moving towards Vision II. (Pilot & Bulte, 2007)

A meta-study by Bennett et.al. (2006) compared 17 studies on the effects of context-based/STS approaches in classes with students aged 11 - 18. Concerning scientific understanding, about half of the studies found that context-based/STS approaches are as good as conventional approaches and another four studies found that context-based/STS approaches were better than conventional teaching methods. In one study (Tsai, 2000), the students showed misconceptions less frequent. Moreover, the meta-study found that in seven of the nine studies measuring students' attitude towards school science, the attitude was more positive for students undergoing context-based/STS programs. This was the case for both girls and boys, and it was found to decrease the attitude gender gap (Bennett et.al, 2006). This is positive given the results of the ROSE project, a study which mapped out the attitudes towards science among teenagers from around the world, where girls in general were found to have less interest in school science than boys (Schreiner & Sjøberg, 2010). Interestingly, one study provided evidence that the 30% lowest performing students developed a better conceptual understanding in context-based/STS classes and that they were more positive towards school science than their lower performing peers in conventional classes (Yager & Weld, 1999). The meta-study concludes that when using context-based/STS methods "there are no drawbacks in the development of understanding of science, and considerable benefits in terms of attitudes to school science" (Bennett et.al., 2006, p. 368).

2.6. Existing resources for chemistry teachers

There already exist a number of resources to help teachers in their educational tasks. In a thesis from 2017, two students at the University of Gothenburg researched what digital resources were used by chemistry teachers in Sweden (Lundberg & Widén, 2017). Data was gathered from 80 upper secondary chemistry teachers and divided into four categories depending on if the user was the teachers or the students, and whether the resources were used in- or outside of the classroom. For the present study, the category "teachers, outside of classroom" was the most interesting, since that targets the planning phase of a lecture, as does the material examined in the present study. In Table 1, the 10 most frequently used resources among chemistry teaches are listed and then described below. It is important to note that relating to

the 80 respondents the frequency descends to under 10% of respondents after the six most used resources.

Table 1. The most frequently used online resources by chemistry teachers, outside of the classroom (Lundberg & Widén, 2017)

Resource	Frequency
Kemilärarnas Resurscentrum	24
Ehinger.nu	18
Skolkemi Umeå	14
Skolverket	10
Youtube	10
PhET	9
Facebook	5
Naturvetenskap.nu	5
Royal Society of Chemistry	5
Khan academy	4

Kemilärarnas Resurscentrum [Chemistry Teachers' Resource Center] (KRC) describes themselves as a national resource centre and are managed by the University of Stockholm and the Swedish Department of Education. Their purpose is to support chemistry teachers in both primary and upper secondary school in order to promote "en stimulerande, intressant och aktuell undervisning" [a stimulating, interesting and current education] (Olander, 2021). They provide first and foremost ideas for laboratory exercises and in-class demonstration, however, they offer other educational material and training and safety advice for teachers as well. Moreover, they work to support the connection between school and the chemical industry (Olander, 2021).

The Swedish upper secondary teacher in chemistry and biology Magnus Ehinger uploads, to his website *Magnus Ehingers undervisning* [Magnus Ehinger's teaching], material related to the courses he teaches. In relation to the chemistry courses, the website contains course schedules, exercises, video lectures, laboratory exercises, old exams, and a list of other online resources (Ehinger, 2020).

The website *Skolkemi Umeå* [School chemistry Umeå] is administered by the University of Umeå and contains instructions for laboratory work and classroom demonstrations to be performed in upper secondary chemistry education (Åberg, 2016).

Skolverket offers information and support for teachers that relates to the regulating documents of the Swedish school system, such as curricula, school acts, support for grading and other information from the government, as described in section 2.1.

Youtube is an online video platform where users can upload videos to their, so called, "channel", in any genre. In relation to chemistry education there are a number of relevant channels, however no specific channel is mentioned by Lundberg and Widén (2017).

The University of Colorado website *PhET* offers free interactive online simulations for all levels of mathematics and science education (University of Colorado, 2021).

The social media platform *Facebook* is used by some chemistry teachers to prepare lessons, according to Lundberg and Widén (2017). Relevant are a number of groups where chemistry teachers exchange educational ideas. However, no specific Facebook-group is mentioned by Lundberg and Widén (2017).

The website *Naturvetenskap.nu* is administered by the upper secondary teacher Jonas Arvidsson. It contains brief explanations of the subjects listed in the Chemistry curriculum.

According to the author the website is firstly intended to help student, but also parents and teachers (Arvidsson, 2021).

The Royal Society of Chemistry (RSC) is a professional association with the goal "the general advancement of chemical science" (The Royal Society of Chemistry, 2021). They carry out research and publish journals and books. Interestingly for chemical education in general, their website contains a searchable database with a wide range of resources and experimentations for all levels (The Royal Society of Chemistry, 2021).

The website *Khan Academy* describes themselves as offering "practice exercises, instructional videos, and a personalized learning dashboard that empower learners to study at their own pace in and outside of the classroom" (Khan Academy, 2021). The courses are based on videos uploaded to Youtube.

Besides the sources mentioned by Lundberg and Widén (2017) one other resource should be mentioned. During "The International Year of Chemistry 2011" the material *Kemikalendern* [The Calendar of Chemistry] was created by the University of Gothenburg, Chalmers University of Technology, the museum Universeum and the Molecular Frontier Foundation. The material contains one topic for each month, that explores the chemistry of work- and everyday life to be used in elementary school chemistry education (Chalmers University of Technology, 2020).

3. METHOD

In order to get both a broad perception and a more in-depth perception as to what chemistry teachers think about the research question, a mixed research method regarding quantitative and qualitative focus was chosen. Practically, this means that the data collection was done in two main stages. First, a questionnaire with a main focus on quantitative information was conducted. Then, a prototype of the material was developed, which was tested by 11 chemistry teachers for five weeks. The second stage of data collection was then to conduct interviews with the chemistry teachers that participated in the user test. These interviews had a main focus on qualitative information in order to identify and assess the different ideas and opinions of the teachers. Prior to the data collection, a literature review was performed in order to set the thesis in context and make sure to design the questionnaire and interviews accurately and effectively. Each of the steps are presented in the following section and an overview of the process is presented in Figure 2.

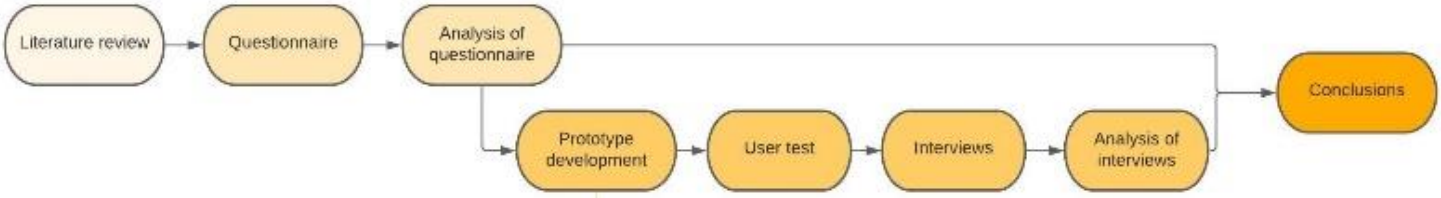

Figure 2. The method represented as a flow chart of the different components.

3.1. Literature review

The first part of the research process was to carry out a literature review. The literature review served two main purposes. The first was to get an initial grasp of the field of research and, thereby, setting this study in context with previous research, as is standard procedure according to Denscombe (2017). This was done by using key words to search for relevant literature through search engines, such as Google Scholar, and databases, such as Education Resources Information Center (ERIC). The keywords used, both separately and in combination with each other, for this part of the literature review were *motivation*, *relevance*, *interest*, *student*, *education*, *teaching*, *scientific literacy*, *context-based learning*, *science-technology-society*, and *Vision II*. In addition, relevant literature was found by backward citation tracking of the already found, key literature, as recommended by Denscombe (2017). All sources that were deemed to be relevant to this study were read systematically. After this initial literature review, the specific research questions for this thesis were formulated.

The second purpose of the literature review was to start mapping out existing material and resources for chemistry teachers. The aim was to see what sort of material already existed, what those materials looked like and whether there already existed a material with the purpose of connecting the curriculum with work- and everyday life. This was done in order to understand what the chemistry teachers might already use and thereby be able to design the questions for the data collection to obtain as high a validity as possible in the answers to the research

questions. For example, that the questions in the questionnaire were designed in a way that minimized misunderstandings and that they measured what they were intended to measure (Esaiasson et.al., 2017). The reading material for this part of the literature review was obtained by browsing the internet, using the key words *chemistry*, *learning*, *teaching*, *everyday life*, *inspiration*, *education*, *idea bank*, *material*, and *resource* both separately and in combination with each other, and through different relevant online forums. One example of an online forum used is the Facebook group *Kemilärarna* [The chemistry teachers].

3.2. Survey

In order to answer the research questions, the first step was to conduct a survey. The survey was divided into three parts. The first part concerned the second research question, "*To what extent do chemistry teachers experience a need for a material making the connection between the curriculum and work- and everyday life?*". The second part of the survey aimed to investigate the first research question "*To what extent do chemistry teacher experience existing material to fulfil the purpose of making the connection between the curriculum and work- and everyday life?*". The third part consisted of questions about the content of such a material, what kind of format it should have and where it should be found in order to be of use, thus aiming to answer the last two research questions, "*What kind of format and platform would be suitable for a material with the purpose of making the connection between the curriculum and work- and everyday life?*" and "*What kind of content would teachers find useful in a new material with the purpose of making the connection between the curriculum and work- and everyday life?*". A survey was chosen due to the characteristics of surveys stated by Denscombe (2017); they concern empirical research, they often reflect how things are at this time, not over a period of time, and they strive for broad perceptions of the population, which fitted the purpose of the present study well (Denscombe, 2017; Esaiasson et.al., 2017).

3.2.1. Questionnaire

The survey method selected for the study was a self-administered questionnaire. Interviews could also have been used as a survey method but was rejected since the main focus was on quantitative information, rather than qualitative. Moreover, questionnaires are a time efficient data collection method when the aim is to reach many respondents (Denscombe, 2017; Esaiasson et.al., 2017; Floyd & Fowler, 2014).

Creating the sample frame

The sample frame for the survey was essentially all active chemistry teachers in Swedish upper secondary school. Concerning such a sample frame, which consists of a set of people who are performing a common activity that makes them interesting for the survey, Fowler (2014) states that "there is not an advanced list from which sampling occurs; the creation of the list and the process of sampling may occur simultaneously." (p. 15). Since this was the case, it was difficult to use a probability sample procedure even though that in general is the best way to achieve representability (Denscombe, 2017). However, in this study the assumption was made that possible differences between people in the sample frame, for example age or geographical location, would not affect their answers to the study's research questions. Representability was therefore assumed to be achieved by reaching as many chemistry teachers as possible and get

as high of a response rate as possible. A high response rate is in itself often considered to be a key to the success of a survey (Esaiasson et.al., 2017).

The difficulty of creating a list of the sample frame was met by using *multistage sampling* as described by Fowler (2014). On each level the probability of selection was 100%, thus the only thing ruling out potential participants was them not fulfilling the inclusion criteria. The first sample level was chosen to be the three largest regions in Sweden: the Stockholm, Gothenburg, and Malmö region. These three, largest, regions were selected as a way to reach as many teachers as possible in a time-efficient way. The next sample level consisted of the upper secondary schools in these regions. There were two criteria for inclusion on this sample level. The first was that the school offered one, or both, of the Nature science program and the Technology program. The second was that the school had the contact information to either the chemistry teachers or a program-specific principal available on their website. Practically, a list of all the upper secondary schools offering the Nature science program and/or the Technology program was found on the website *gymnasium.se* (Education Media Group, 2021). From there, each school's website was visited in order to see whether or not contact information was available. Each, available, chemistry teacher's, or program-specific principal's contact information was then gathered in a separate list to create the final sample level. This list of teachers and principals was considered the final selection of participants, to whom the questionnaire was distributed. The questionnaire was also distributed to chemistry teachers in the social media networking group *Kemilärarna* [The chemistry teachers] with 1700 members on Facebook. This was done in order to reach a large part of the sample frame in a time-saving way. All in all, the questionnaire was sent out to 24 program specific principals and 149 teachers, excluding the members of The chemistry teachers. There were 59 respondents to the questionnaire.

Creating the questionnaire

When creating the questionnaire, the starting point was the research questions. The purpose of the survey was to answer the first three questions and to gather enough information on the fourth, "*What kind of content would teachers find useful in a new material with the purpose of making the connection between the curriculum and work- and everyday life?*", to build a prototype exploring this further. The questions could, of course, be asked as they are stated here, only directing them to the respondent. However, firstly, as Esaiasson et.al. (2017) notes, it is important to avoid both complicated wordings and difficult phrases in survey questions. It is not at all certain that respondents understand these questions in the same way as someone who has read them in the elaborated context of this thesis (Fowler, 2014). Secondly, asking these questions as they are stated here would undermine the possibility to explore and deepen the answers. For example, consider the second research question, "*To what extent do chemistry teachers experience existing material fulfil the purpose of making the connection between the curriculum and work- and everyday life?*". If some teachers were to answer "To a low extent.", it is not possible to know why that is the case. It could mean that they do not consider it to be of importance to make said connection, or perhaps they simply do not have a material making the connection, or something else entirely.

To avoid such problems the research questions were carefully considered and a total of eight main questions were constructed. Aspects such as unambiguity and pre-stated options were kept in mind. On some questions, the respondents were asked to answer on a scale between 1 and 5. This scale was purposefully constructed with "3" as an alternative in the middle. For

example, in one question the respondents were asked to rank to which extent they think a number of online resources fulfils a specific purpose, between 1 (To a low extent) and 5 (To a high extent). In this case the alternative "3" would provide useful information, meaning "to some extent", even if it is the middle alternative. As Esaiasson et.al. (2017) state, the middle alternative could be misused by people not wanting to take a stand in the matter. However, in such non-controversial matters this is hardly a concern and for respondents not familiar with the resource in question, there was a "no perception"-option.

In three of the eight main questions, there were pre-stated options. The first of these concerned how well the teachers felt that existing material fulfilled the purpose of making the connection between the curriculum and work- and everyday life. The second of these questions concerned how teachers found the material they already use and the third concerned possible categories for the material and how useful the teachers would find these categories. The pre-stated options to these questions were selected partly from the Lundberg and Widén (2017) study described in section 2.6. and partly from brainstorming sessions where the authors own experiences as teacher students were taken advantage of.

Further on, all questions in the questionnaire were followed by the opportunity to leave a comment in relation to the question or one's answer. This was optional and added in order to not lose any information the respondent was willing to give. The questionnaire is presented in its entirety in Appendix A.

Another possible issue is what Esaiasson et.al. (2017) call *construct validity*, that the questionnaire might end up measuring something other than what was intended. According to Esaiasson et.al. (2017) the problems with construct validity becomes greater when the distance between the theoretical constructs and the used empirical indicators increase. This distance was deemed to be small in the present study and the potential issues were taken into consideration by using the strategy *face validity* when designing the questionnaire- and interview questions. That means that each of the question was thoroughly considered to avoid misunderstandings and be as clear as possible (Esaiasson et.al., 2017).

As advised by Denscombe (2017) the questionnaire was sent to a few peers and then updated according to their feedback before it was sent out to the respondents. One week after the initial email was sent, a reminder was sent out in order to increase the response rate (Denscombe, 2017).

3.2.2. Analysis of questionnaire

The questions in the questionnaire were univariable, with the exception of one of the introductory questions which was bivariable. All questions were either on a nominal scale, with the purpose of classifying the respondents into different categories, or on an ordinal scale, with the purpose of ranking the respondents on a pre-determined scale (Esaiasson et.al., 2017). One example of a question on a nominal scale is "*Do you have access to a material connecting the curriculum with work- and everyday life?*", to which the respondents could answer "Yes", "No" or "Partially". One example of a question on an ordinal scale is "*How useful would you find the following categories in a material making the connection between work and everyday life?*", to which the respondents were supposed to rank different suggested categories on a scale from 1 (Not useful) to 5 (Very useful).

The univariable questions on a nominal scale were analysed using mode values and, in addition, with the frequencies of the different answers, as recommended by Esaiasson et.al. (2017). Mode values are recommended by Esaiasson et.al. (2017) in the case of ordinal scale questions as well. However, Denscombe (2017) states that arithmetic mean values can be used as well. Mean values were presumed to give a more representative picture of the results of the ordinal scale questions in this questionnaire and was therefore used when analysing the result.

3.3. Prototype

To obtain further information on what a full version of a material with the purpose of connecting the curriculum with work- and everyday life, should contain, and to validate some of the results from the questionnaire, a prototype was developed. The prototype was tested by a number of chemistry teachers for five weeks. The following section describes the process of developing the prototype, performing the user test, evaluating the user test, and analysing the result.

3.3.1. Prototype development

Once the survey had been conducted and evaluated together with the literature review, the process of developing the prototype started. The prototype is presented in its entirety in Appendix C. The purpose of the prototype was to ensure common ground during the interviews, to catalyse a more in-depth discussion and to see how teachers want to use this kind of material. The prototype includes two of the areas from the Core content in the Chemistry 1 curriculum, which were selected to correspond with the course plan of the teachers participating in the user test of the prototype, described in the next section. The two areas were "Acids and bases" and "Redox-chemistry".

Each of these areas then consisted of a number of categories that were selected based on the results from the survey. In one of the questions in the questionnaire, the respondents were asked to rank the following categories, "Interviews with professionals", "List of occupations", "Rationale from Skolverket", "Everyday phenomena" and "Everyday products", on a scale from 1 to 5 depending on how useful they would find them in a material that connects the curriculum with work- and everyday life. The criteria used for selection of which categories would then be included in the prototype, was getting a mean value of 3 or higher on this question. In addition to the provided alternatives, the respondents were given the opportunity to make suggestions of their own using short text-answers. From the short text-answers, the suggestions that were deemed to fit within the purpose of the material were included in the prototype.

After deciding the categories, three particular aspects regarding content were identified from the literature review and the survey results. The first identified aspect was "Level of connection to sustainable development", that is, how well the content is concerned with sustainable development topics. The second was "Level of comprehensiveness", that is how deeply the material goes into each example. The third aspect was "Level of concretion in the connection to the curriculum", which is how straight forward the connection is between the theory, in an example, and what it says in the Core content. The prototype was then developed so that each of these aspects were included in different manners so that the teachers could try the different

versions during the user test and then evaluate them during the interviews. By doing this, the aim was to be able to deliver an in-depth answer to the fourth research question "*What kind of content would teachers find useful in a new material with the purpose of making the connection between the curriculum and work- and everyday life?*".

For each of the categories, different examples were included that somehow connected that category to the specific area in the Chemistry curriculum. The subjects for the examples were found by looking at already existing resources, for example School chemistry Umeå and The Calendar of Chemistry, and by browsing the internet.

In the end, the prototype consisted of one section for "Acids and bases" and one section for "Redox-chemistry", each containing the categories "Everyday phenomena", "Everyday products", "Historical events" and "News". Each of the categories then consisted of one or multiple examples describing a phenomenon, a product, a historical event, or a piece of news, that is connected to "Acids and bases" or "Redox-chemistry" respectively.

3.3.2. User test

Once the prototype had been developed, a user test was conducted in order to evaluate the prototype. The participants in the user test were chemistry teachers who were to teach in the course Chemistry 1 during the time they would have access to the prototype. These teachers were found by asking for volunteers in the questionnaire from earlier in the process. In this questionnaire there was a link to another survey in which teachers could express their interest in participating in the user test and leave their contact information, while maintaining anonymity in the questionnaire. From the 59 respondents in the questionnaire, 20 teachers expressed their interest in the user test. The prototype was sent out to these 20 teachers to use for a duration of five weeks. Their instructions were to use the prototype as they saw fit within their teaching and planning. From these 20 teachers, 11 registered to participate in interviews in order to evaluate the user test.

3.3.3. Interviews

To evaluate the user test, semi-structured interviews with the participating teachers were used. The major aim of the interviews was to get data that could be used to get a more detailed understanding of the last two research questions, "*What kind of platform would be suitable for a material with the purpose of making the connection between the curriculum and work- and everyday life?*" and "*What kind of content would teachers find useful in a new material with the purpose of making the connection between the curriculum and work- and everyday life?*".

The format of semi-structured interviews is suitable when the desired outcome is to understand the respondent's perception of a particular matter, when the subject or the required answers are of a more complex nature and when the interviewer wishes to be able to follow up on different answers during the interview (Denscombe, 2017; Esaiasson et.al., 2017). Semi-structured interviews were therefore selected in this stage of the study as the purpose was to get a deeper understanding of the teachers experience with the prototype in order to deepen, verify and/or re-evaluate the previously obtained answers to the research questions. Another advantage of semi-structured interviews is that they are particularly suitable when collecting qualitative data (Denscombe, 2017). Compared to the survey, which mainly concerned quantitative data, this part of the data collection focused on qualitative data, making semi-structured interviews a

suitable approach. Moreover, semi-structured interviews provided the opportunity to reveal what the teachers might have overlooked on their own (Esaiasson et.al., 2017).

In order to easily be able to make the comparison between the results from the questionnaire and the views of the teachers that performed the user test, the interviews were complemented with similar questions to those of the questionnaire, see Appendix B.2. For example, the interviewees were asked to rank the different categories from the prototype according to how useful they found them on a scale from 1 (Not useful) to 5 (Very useful). These survey questions were asked during the interview, where the teachers could tell the interviewer what alternative they wanted to choose. The interview guide used for the other interview questions can be found in Appendix B.1.

The interviews were carried out digitally via the video-conference tool Zoom, using both video and audio. In order to increase the reliability, that is minimizing random errors such as, for example, mishearing something during the interviews or transcribing some part of the interviews erroneously, a number of measures were taken. The first was that both authors participated during the interviews. One took notes so that the other, who acted as interviewer, could focus entirely on the interviewee. The second was recording the sound from the interviews, after getting the consent of the interviewee. The third measure for increasing reliability was that both authors listened to the recorded interviews, in their entirety, at least once after the live interviews in order to complete the notes and make sure they were accurate.

3.3.4. Analysis of interviews

Once the interviews were completed, the work of analysing the interview responses began. An overview of the process can be seen in Figure 3. The first step in analysing semi-structured interviews is, according to Esaiasson et.al. (2017), to summarize the material in order to get an overview. Esaiasson et.al. (2017) presents different techniques for summarization, for example *koncentrering* [condensation], *kategorisering* [categorizing] and *berättande* [story telling]. The analysis of the interviews was done mainly on a manifest level, that is the main focus was on what had been said explicitly rather than "reading between the lines" (p. 281), for which Esaiasson et.al (2017) recommend using condensation as a summarization method. The condensation was carried out while converting the data from its raw format, audio, into text, see Figure 3. This was done in a computer-assisted qualitative data analysis software recommended by Denscombe (2017), called NVivo. The resulting text was a condensed

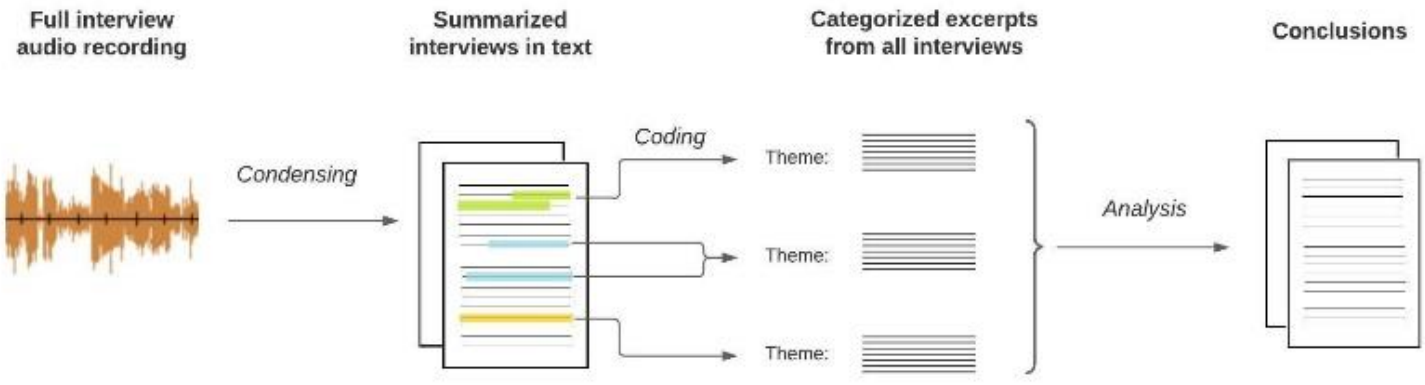

Figure 3. Flow chart of the interview analysis process.

version of the interview responses sorted in time-span slots corresponding to the correct part in each interview's audio file. The alternative would have been to transcribe the full interviews, which is common when doing a qualitative analysis on data from interviews, and then using condensation to summarize the full interview texts. This method was rejected due to being very time-consuming. Since the analysis mainly had a manifest focus and there was no need to discern patterns or latent thoughts from the interviewees, this choice of method was thought not to affect the validity of the study. Denscombe (2017) states that some of the advantages of transcribing is that the researcher gets closer to the data and, therefore, the data becomes more alive to the researcher. To not lose this advantage, the interviews were all listened to in their entirety, at least once, while doing the condensation.

Once the condensation was completed, the next step was to start generalizing the data, to look at all interviews together, in order to be able to draw conclusions regarding the research questions. To do this, a number of different themes, with basis in the research question, were selected, for example, "Content" and "Platform". The coding function in NVivo was then used to mark, or "code", different parts of each of the condensed interview responses according to which theme that part corresponded with. For example, every time someone mentioned anything concerning a potential platform, that part of the interview was coded as "Platform". Each theme then consisted of all relevant responses, from all the interviews. The different themes were then analysed to see what the teachers as a whole had said, and from there the conclusions were drawn regarding the research questions.

Since this part of the data collection had a focus on qualitative data, the aim was to make visible the different opinions and ideas of the interviewed teachers, rather than investigating the frequencies of them (Esaiasson et.al., 2017). Therefore, in the result, the effort was made to present all relevant opinions and ideas, in a structured manner. The survey questions asked during the interviews, however, had the same quantitative character as the questionnaire. The results from these particular questions were therefore analysed in the same way as the questionnaire results, by using mean values and frequencies. The conclusions regarding the research questions were then drawn after discussing the result.

4. RESULT AND DISCUSSION

In this section the gathered result to each of the research question is presented and discussed. The section is divided into four sub-sections, see Figure 4. The first contains the result of the first two research questions "*To what extent do chemistry teachers experience existing material to fulfil the purpose of making the connection between the curriculum and work- and everyday life?*" and "*To what extent do chemistry teachers experience a need for a material making the connection between the curriculum and work- and everyday life?*". The second sub-section contains the result of the third research question, "*What kind of format and platform would be suitable for a material with the purpose of making the connection between the curriculum and work- and everyday life?*" and the third sub-section contains the result of the fourth, and last research question "*What kind of content would teachers find useful in a new material with the purpose of making the connection between the curriculum and work- and everyday life?*". Each of the sub-sections are concluded with a discussion of their particular result. The last sub-section contains an overall discussion of the methods used during this study, including recommendations for further research.

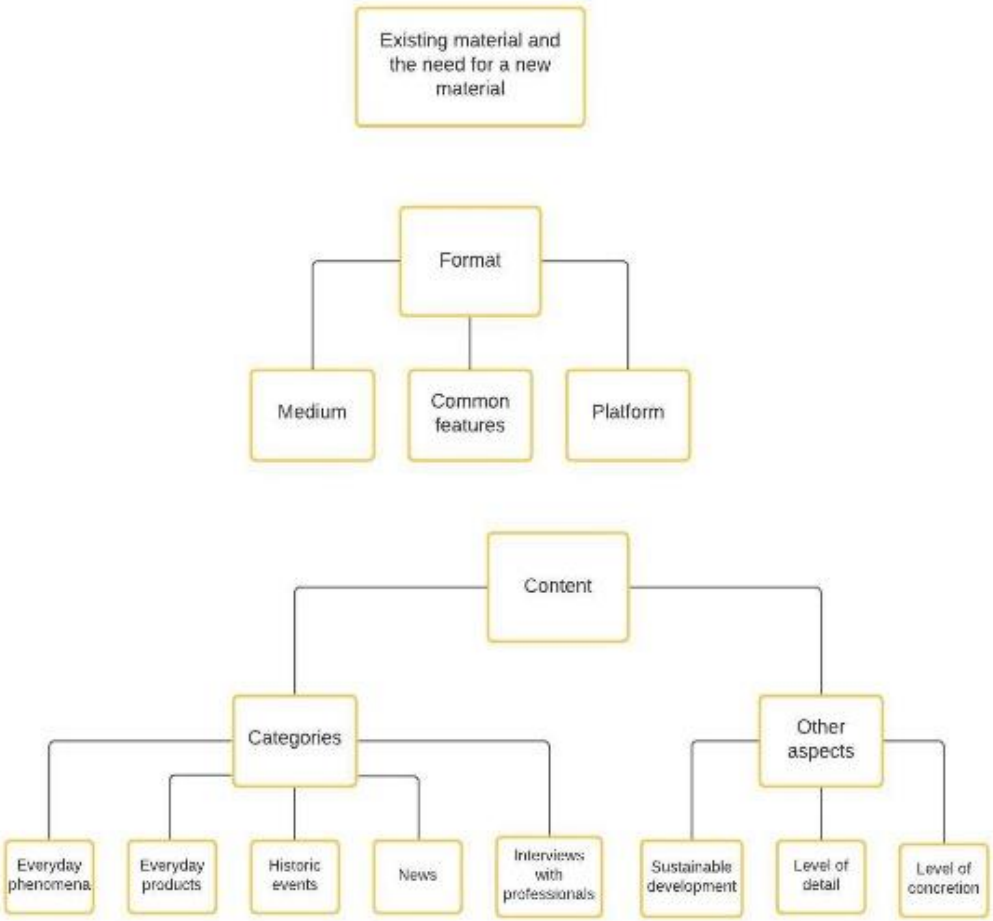

Figure 4. Structural overview of the results of this study.

A couple of notions are important to make before moving on to the results. The questionnaire and the interviews were both performed in Swedish. This means that the questions and quotations presented in this report, have been translated by the authors of this study. Another notion concern mean values and percentages of respondents to the survey. When a mean value or percentage is used in relation to a question where "No perception" was an option, the respondents who selected "No perception" are left out of calculations, if nothing else is stated.

4.1. Existing material and the need for a new material

In the questionnaire, the respondents were asked to rank some of the resources from the study performed by Lundberg and Widén (2017), in relation to their usefulness in making the connection to work- and everyday life on a scale from 1 (To a low degree) to 5 (To a high degree). There was also a "No perception" option. The result is presented in Figure 5.

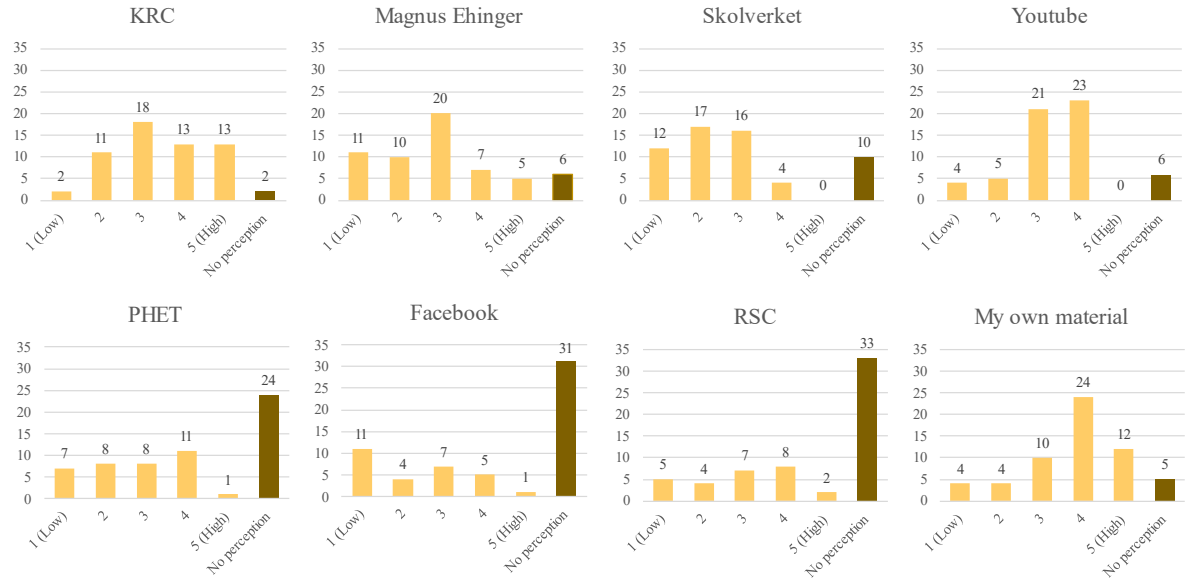

Figure 5. The distribution of answers, in number of responses, to the question "To what degree do you experience existing material to make the connection between the curriculum and work- and everyday life?"

The highest rated resource was "My own material" which is material that the teachers themselves have put together or gathered. This resource had a mean value of 3.7 and 67% of respondents answered 4 or 5. The second highest rated source was "KRC" (Chemistry Teachers' Resource Centre) with a mean of 3.4 and 46% answering 4 or 5. "Youtube" had the third highest mean value, 3.2, and 43% answering 4 or 5. As stated in section 2.6, Youtube is a video platform for all genres of videos, thus the usefulness could be greatly dependent on what particular channel(s) are thought of. Channels mentioned in the questionnaire by respondents were, "Acapella Science", "AsapScience", "Crash Course", "It's Okay to be Smart", "Kurtzgesagt - In a Nutshell", "NeilRed" and "Periodic Videos". The only channel to be named more than once was "Crash Course", which was mentioned twice. Magnus Ehinger's Teaching had a mean rating of 2.7 and 23% answering 4 or 5. One respondent commented that Ehingers material is great for explaining chemistry, but not for making connection to everyday life. "Skolverket" has the lowest mean, 1.8, and 8.1% of respondents answered 4 or 5. Regarding "PHET", "Facebook" and "RSC" (Royal Society of Chemistry), respondents to a

high degree, 40% or more, selected the "No perception"-option. Some other sources were brought up through the text answers. Among these were Sweden's public radio and TV services UR, SR and SVT, where SVT was mentioned twice.

Further on, in the questionnaire the respondents were asked if they already have access to a material making the connection between the curriculum and work- and everyday life. This question was followed by the question "*If you responded 'No' or 'Partially' on the previous question, do you experience a need for such a material?*", as seen in Figure 6. A majority of respondents, 35 in number and 59%, stated "Partially" on the first question. 9 respondents (25%) responded "No" and 15 respondents (25%) said that they do have access to a material making said connection. The other question was answered by the 44 respondents who selected "No" or "Partially" on the first. Out of these 44 respondents, 28 (64%) reported that they do experience a need for such a material. Looking at all respondents these 28 make up 47%, meaning that at least 47% of responding teachers experience a need for a material making the connection between the curriculum and work- and everyday life.

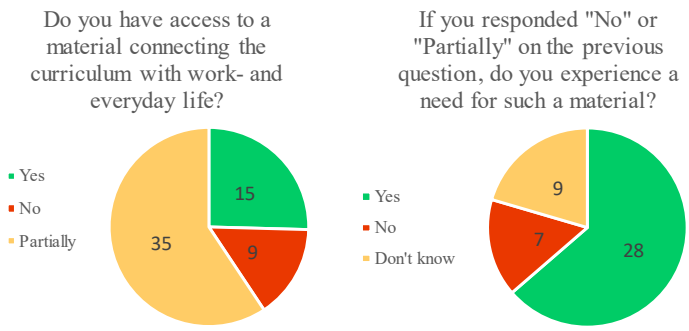

Figure 6. The distribution of answers, in number of responses, to the question "Do you have access to a material connecting the curriculum with work- and everyday life?" (left) and the follow-up question "If you responded "No" or "Partially" on the previous question, do you experience a need for such a material?" (right).

As a part of the research of teachers' need for a material connecting the curriculum to work and everyday life, their attitude toward making such a connection was measured. The respondents of the survey were asked to rank the degree to which making the connection to work- and everyday life affect their teaching in a positive way, on a scale between 1 (To a low degree) to 5 (To a high degree). As can be seen in Figure 7, teachers tend to think positively about the connection to work- and everyday life. The mean value of the answers is 4.0, and 73% of respondents answered 4 or 5. Among the respondents that chose to comment the question, 19 mentioned that making said connection was positive for student motivation or interest in one way or another. However, some teachers were concerned that making connections to work- and everyday life would take time from teaching the traditional, theoretical content of the chemistry courses. Some teachers expressed the importance of rooting examples in the curriculum.

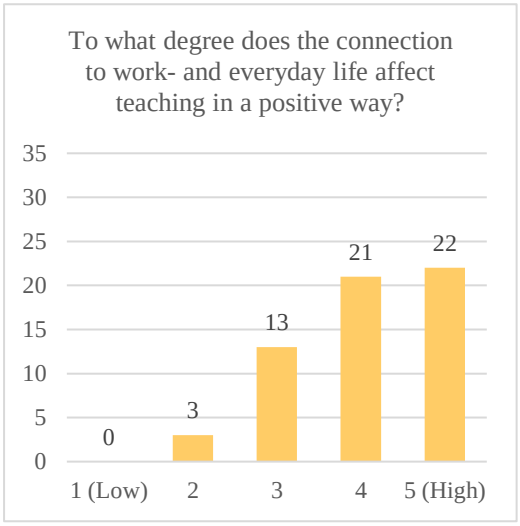

Figure 7. The distribution of answers, in number of responses, to the question "To what degree does the connection to work- and everyday life affect teaching in a positive way?".

On a similar note, the respondents were asked if they found it easy or difficult to make the connection to work and everyday life, see Figure 8. Between 1 (Easy) and 5 (Difficult) the mean value was 2.8. The teachers who commented the question gave different reasons for their answer. Among those who thought it was difficult to make the connection the most common reason was there not being enough time, either in class or when planning, or both. On the other end of the spectrum, teachers who thought it was easy to make the connection gave various reasons for this. Some teachers said that it is easy to find material, other teachers found it easy because they themselves have worked with chemistry before, or at least were experienced teachers who had gathered material over the years. This was also brought up in the interviews, where interviewees expressed that this kind of material might be of greater importance for new teachers or teachers without experience from a chemistry-related vocation earlier in their career.

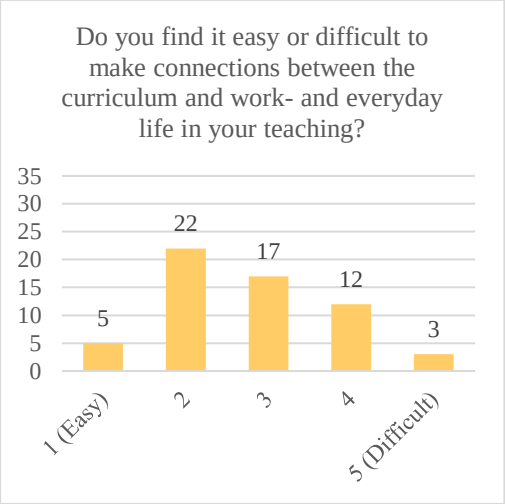

Figure 8. The distribution of answers, in number of responses, to the question "Do you find it easy or difficult to make connections between the curriculum and work- everyday life in your teaching?"

A few interesting notions emerged from the interviews concerning teachers' attitude towards making the connection between the curriculum and work- and everyday life. The main concern was that the course Chemistry 1 contains too many areas which has to be taught in detail to have time for connections to work- and everyday life. One teacher noted that the curriculum for chemistry in grade seven to nine, that is the grades prior to upper secondary school, focuses on chemistry in society to such an extent that when students reach upper secondary school, they have very little understanding of chemical theory. This means, according to the teacher, that upper secondary teachers must lay the theoretical foundation of chemistry. The need for focus on the basic theoretical concepts was brought up by another teacher as well. This teacher said that "*the student struggle to think outside the box because they have such empty boxes*". Other teachers expressed a will to include more connections in their teaching. This will was expressed literally by some teachers, while others merely expressed a concern about students viewing chemistry as detached from everyday life.

4.1.1. Discussion of "Existing material and the need for a new material"

As mentioned in the introduction, the idea for this thesis was the notion that there is a lack of a material making the connection between the curriculum and work- and everyday life, often resulting in teachers having to create or gather their own material. This observation, or hypothesis, have to some extent proven to be correct. The highest rated source was "My own material", and teachers report that a new material might be most useful for new teachers who yet have not had the time to gather their own. Thus, even though teachers generally think it is neither hard nor easy to make the connection, it appeared to be a question of experience; teachers with more experience or who have had a chemistry related vocation earlier in their career thought it was easier than others to make the connection. However, even though "My

own material" was the highest rated source, the mean rating was not higher than 3.7 on a five graded scale, and when they were asked if they had access to a material making the connection, only 25% answered "Yes". This would suggest that for most Swedish chemistry teachers in upper secondary school, there is no source, that they know of, that makes the connection to work- and everyday life in satisfactory way. Furthermore, almost half of teachers reported the need for such a material and the wish to include more, or better connections to work- and everyday life in their teaching was frequently mentioned in the interviews. On the bases of this it could be argued that there is a widespread need for a material making the connection between the curriculum and work- and everyday life among chemistry teachers.

The pursuit towards connections between the curriculum and work- and everyday life was not, however, met with applause by everyone. One reason for this was the concern that such an endeavour would disqualify the study of chemistry on the basis of mere curiosity. This raised an interesting question concerning the Vision II of scientific literacy (see section 2.5.). Is there a risk that the pursuit of Vision II undermines pure academic studies? It appears that some teachers think that it does, because chemistry should be encouraged to be studied regardless of its applications in technology and everyday life. However, even if this might be true, the more interesting question is of what importance this should have for upper secondary studies. While academic sciences at universities can be free from demands of applicability, does that mean the same should be true for upper secondary science education? After all, upper secondary science is to be taught to a much broader part of the population than students who aim to be researchers in a nature science field. It could then be argued that it is the responsibility of upper secondary science to make itself relevant to all students. For even though science could be studied on the bases of curiosity alone, teachers in this study frequently lift the potential to motivate students by connecting the teaching to work- and everyday life.

As mentioned above, the main concern among the teachers was that the course Chemistry 1 contains too many areas which have to be taught in detail, which limits the time available for connections to work- and everyday life. This implies that connections to work- and everyday life is something separate from the theoretical material by necessity, which is a view closely linked to a Vision I of scientific literacy. A Vision II way of viewing this would be to see the work- or everyday situation as a medium in which the theoretical content can be taught and explored. This might imply that a change of teachers' mindset could be needed for this kind of material to reach its full potential.

The different resources given as pre-stated options to the question "*To what degree do you experience existing material to make the connection between the curriculum and work- and everyday life?*" were selected partly based on the result of the Lundberg and Widén (2017) study, presented in section 2.6. The result of that study and the present study vary greatly when asking what online resources are used by chemistry teachers. This difference might be due to the methods used. In the Lundberg and Widén (2017) study, participants were asked to write down their used online resources in text answers, without any pre-stated options to choose from. This led to fewer reports of each source than in the present study, where participants were asked to rank pre-stated options. For example, Lundberg and Widén (2017) report that 24 out of 80 respondents (30%) use KRC, meaning that 70% either do not know about, or, at least, do not use KRC when planning lessons. In the present study, only 2 out of 59 respondents (3.4%) selected the "No perception"-option, meaning that close to 97% claim to know enough about KRC to rank the degree to which they experience it to make connections to work- and

everyday life. The difference between 30% and 97% is, of course, noteworthy. This could mean that when asking respondents to write down resources on an empty paper some will be forgotten. On the other hand, this could also mean that when presented with pre-stated options, participants tend to answer based on their limited knowledge instead of admitting that they in fact know too little to answer the question thoughtfully. In the present study, however, the teachers experience of the matter was the interesting parameter, rather than the actual extent to which the source made connections to work- and everyday life.

In the Lundberg and Widén (2017) study, the website School chemistry Umeå was reported to be one of the most used sources for chemistry teachers outside of the classroom. In the present study this source was excluded due to the initial notion that it was a mere collection of laboratory instructions. Looking back, School chemistry Umeå should have been included in the questionnaire since it does in fact make several connections to work- and everyday life in the attempt to create contexts and deepen the theoretical explanation of the laboratory exercises. However, School chemistry Umeå was not mentioned by any participant, neither in the questionnaire nor the interviews. Whether this means that respondents simply forgot about School chemistry Umeå or if it is not widely used, this study cannot say.

4.2. Format

During the interviews with the teachers that performed the user test of the prototype, the question "*What kind of format would you want this material to have?*" was asked. This question was asked in order to be able to answer the third research question, "*What kind of format and platform would be suitable for a material with the purpose of making the connection between the curriculum and work- and everyday life?*". The result is presented below and divided into two parts. The first is format concerning which type of medium the material should be presented in and the second is features regarding format in general that the teachers wished this kind of material to have.

4.2.1. Medium

One of the suggestions brought up during the interviews was that the material should have the format of a printed book. The teachers suggesting this found printed material to be easier to assimilate.

"*I am a friend of books and printed materials. I think they are easier to assimilate.*"

Another suggestion was that the material could be in a PDF-format, as the prototype was. The teachers suggesting this personally liked the PDF-format.

"*I am used to, and can't come up with another way* [than PDF] *that I would prefer.*"

The third suggestion regarding format was to have the material as a website or web-based database. One advantage brought up by the teachers regarding a website format is the possibility to keep it updated, for example with regards to references, links, information, news, etcetera. Another advantage is that a web-based format enables easy sharing with students and other teachers, thereby making the material more available. The teachers also said they would appreciate the possibility to easily download and use the different figures in the material. A

web-based format would enable having videos and animations as a part of the material, something that the teachers wished for. Such videos and animations, the teachers thought, would be useful for the students in order to increase and facilitate understanding of the material, and to make it more fun. A suggestion was made to incorporate young and enthusiastic people in these videos in order to present the material in an engaging way and present role models for the students. It was mentioned during the interviews that if the material is to have a web-based format, the benefits of that format needs to be taken advantage of, for example using videos, links, being able to search the site, and click your way to the right content, etcetera.

"*If you have* [the material] *on a platform, a website, then you have the possibility to update it, make sure the links always work, and add new information when that comes along. So, in the long term maybe it is better to have* [the material] *on a website*"

"*I always think that everything that is web-based is easy to handle when it comes to sharing with the students. They can go to the website and read some parts, and you can also click on links to explore further* […] *So, some kind of digital platform.*"

"*Short videos would be very appreciated."*

"[The material] *should be digital,* […] *then there could be more illustrations and animations.* […] *There are amazing American and English lectures with young adults. Then they can become role models as well. That is a very good format* […] *when young students, that are really passionate about what they do, can explain. That is really good pedagogically.*"

The fourth suggestion was to have the material as a website and then have an associated application. This would, according to the teacher who suggested it, mean that the material is easily available.

4.2.2. Common features

Some wishes and advice from the teachers regarding format and functions for the material is applicable somewhat irrespective of which medium the material would be presented as. The teachers said it was important to have a clickable table of contents to be able to easily navigate the material and that it should be sorted according to which part of the Core content it was connected with (as in the prototype). This could be implemented both in the format of a PDF and in an interactive website.

"*I thought it was really good that the table of contents was clickable* [in the prototype]."

It was also brought up during the interviews that there was a wish for a lot of illustrations to make it easier to understand the material. Examples of usable illustrations were flow charts, chemical structures, chemical equations, and general illustrations of things described in the texts.

"*What I often miss as a chemistry teacher is good figures. There could be flow charts, molecular structures or some other kind of figures such as cycle processes.*"

"*The text can generate questions that could be answered with illustrations.*"

The teachers in general appreciated a lot of references to where the information was from and links to further reading. Links enabled teachers to feel confident that the information was

reliable and to read more if they wanted or needed to. Furthermore, it helped the teachers make the case to the students that it is important to use references in your work. One teacher gave the advice to include a short description of what each link led to, for example what information you would find, what topics you could read more about, and whether it was a link to a research paper, a laboratory manual or something else.

"*What I like is all the references so that you can really find out more. That, I really appreciated.*"

"*The references are important so that you can see where things come from.* […] *If you come to Royal society of Chemistry* [for example], *then you know it is for real. It gives it more weight.*"

"*It is really good* [to have references] *because you always tell your students that it is important to think about what kind of references you use.*"

"*When there are links to 'Read more', it would be very useful to know what there is on these links. 'Here are some tips for experiments' or 'Here are more information regarding this part of the material', not just 'Read more' so that you yourself have to find out what is on the link.*"

The final advice regarding common features was to adjust the language in the material to the students' level. That way, the material would be easier to use as a student material as well.

"*Some of the words* [used in the prototype] *I understand as a chemistry teacher, but as a student it could be difficult.* [In one example in the prototype] *the word 'aerosol' is mentioned, and that is something that you use as a chemist, but I don't think that many students know what it is.*"

4.2.3. Platform

The question of what platform would be suitable for this kind of material was studied through both the questionnaire and the interviews. It should be noted that the suitability of different platforms to some extent is dependent of the format of the material. If the material is a PDF, another platform might be more suitable than if the material is an interactive website.

However, in order to differentiate what platform could be suitable, the respondents of the questionnaire were asked how they found the material they use in their teaching as of today. As can be seen in Figure 9, the most common way to find new material for teaching is through “Google”. The use of Google for this cause was reported by 49 of the respondents (83%). An almost equally common way to find new material is to get it through colleagues, as 46 of the respondents (78%) selected that option. The least frequently used of the pre-stated options was “Skolverket”, which was reported to be used by 13 of the teachers (22%). Other pre-stated options were “Teaching aid manufacturers”, which 27 respondents (45%) had used and “Online forums”, which were used by 19 respondents (32%).

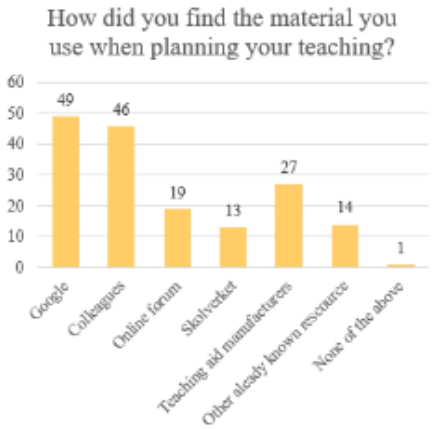

Figure 9. The distribution of answers, in number of responses, to the question "How did you find the material you use when planning your teaching?" More than one option could be selected.

In addition to the pre-stated options, respondents had the possibility to add their own answers. The most frequently answered source of material was from news media, which was answered by two respondents. Furthermore, respondents were asked to comment their response to this question, and if they had selected “Online forum” they were asked to specify. The most common online forum to be referred to was Facebook, which was stated six times, however, no specific Facebook-group was mentioned here.

In the interviews the question of platform was brought up again. This time the teachers were asked “What are crucial aspects for making the material found and used?” One teacher answered *“Smart marketing; it does not have to be expensive. It could be posted to Facebook-forums* [and] *spread through aimed emails.”* Other teachers answered similarly, and many teachers suggested KRC as a suitable platform to make this kind of material found and used. One reason, mentioned by the teachers in the interviews, for why KRC would be a suitable platform was that a lot of teachers already have knowledge of, and frequently use, KRC, “*KRC is a good way to reach chemistry teachers*”. Another reason given was that KRC review the material published on their webpage, making it trustworthy. The use of KRC, however, presupposes that the material is web-based. Suggestions that are neutral to the question of medium were, for example, to introduce the material in meetings with teachers on schools. Another such suggestion was to partner with, or release the idea to, teaching aid manufacturers.

4.2.4. Discussion of ”Format”

Even though multiple mediums were brought up during the interviews, most of the mentioned features that the teachers would like to have, for example videos, animations, and search functions, are only possible if the material is web-based. The interviewed teachers who preferred printed books or a PDF-files mainly did so out of personal preference. Since this opinion showed up during the interviews, however, one can assume that there are more teachers out there that share the preference to printed material. One way to combine preferences could be to include a printable PDF-version of the material on the final website. That way, teachers who prefer to do so can print out the material. It is worth mentioning that the prototype of the material, used by the interviewed teachers, was a PDF-file. It is possible that this affected the teachers views on suitable mediums. Therefore, not only the explicit answers to the question

about medium, but also answers to questions about, for example, which kind of features should be included, was taken into consideration when drawing conclusions regarding medium.

Regarding platform, the two highest ranked methods in the questionnaire for finding new material were “Google” and “Colleagues”. In addition, the highest ranked resource for making the connection between the curriculum and work- and everyday life was “My own material”. This suggests that teachers, for the most part, do not consult any specific provider of teaching aid in order to find new material. Thus, if a new material is to be found by teachers, it appears it must be found when searching relevant terms on Google. However, this leaves the material to Googles complex search algorithm, which is outside of the scope of this study. Looking at other platforms, the most suggested was KRC, which was mainly brought up during the interviews. Even though not as frequently used as simply using Google, this appears to be a fairly visited website which could be used as a platform for this material. KRC also have the advantage of reliability, since the material on the platform has been reviewed, as mentioned by some of the teachers in the interviews.

“Skolverket” was ranked the lowest of the pre-stated options in the question concerning how teachers locate new material. The same is true for when teachers were asked to rank the usefulness of different sources in making the connection between the curriculum and everyday life. This is interesting because one could easily think that the teachers see *Skolverket* as a resource since it is the national agency for education. As stated in section 2.1, the purpose of *Skolverket* is to establish frameworks by, for example, creating regulatory documents, support improvement work and provide in-service training to teachers. *Skolverkets* main purpose is not, therefore, to provide teaching resources or materials. This could be why the teachers do not look to *Skolverket* when looking for new material, or find them useful for making the connection between the curriculum and work- and everyday life.

4.3. Content

In both the questionnaire and the interviews, the teachers were asked what kind of content they would find useful in a material that connects the curriculum with work- and everyday life. In this section, the result is presented concerning what kind of categories should be included in the material. The section also includes the teachers’ opinions on some other aspects such as, for example, sustainable development, and other additional information regarding the content.

4.3.1. Categories

In the survey, the respondents were asked to rank a number of categories on a scale of 1 to 5 by how useful they would find them in a material connecting the curriculum with work- and everyday life, where 1 represented “Not useful” and 5 represented “Very useful”. The suggested categories were: “Everyday products”, “Rationale from Skolverket”, “List of occupations”, “Everyday phenomena”, and “Interviews with professionals”. The result is presented in Figure 10. The respondents found “Everyday phenomena” to be the most useful category with a mean value of 4.4 and 83% answering 4 or 5. “Everyday products” was also

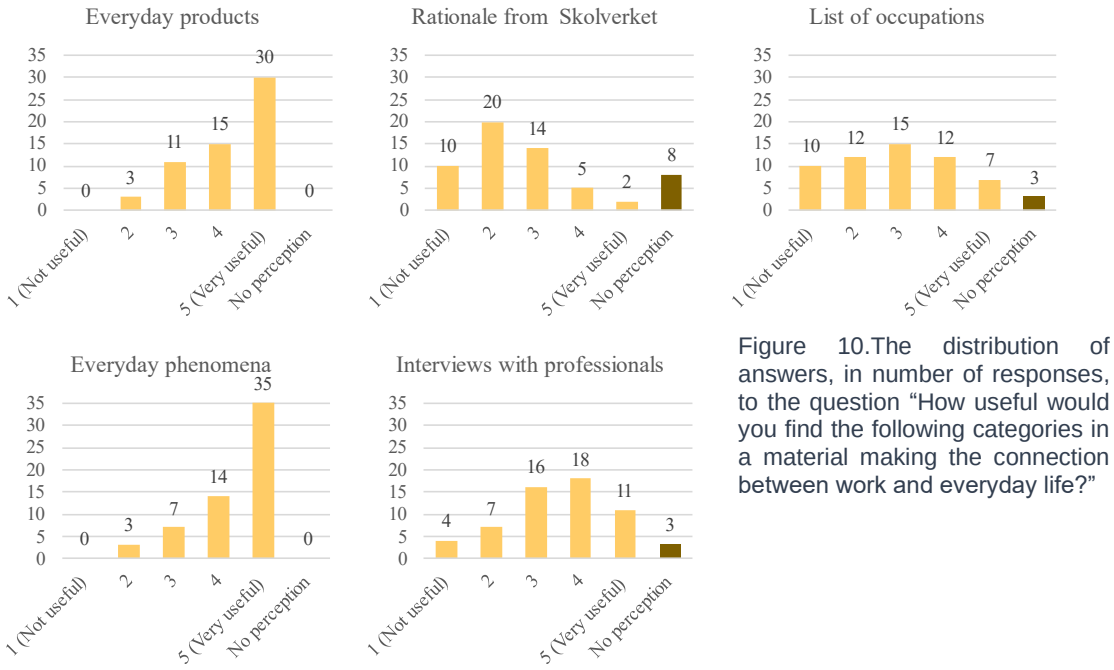

Figure 10.The distribution of answers, in number of responses, to the question “How useful would you find the following categories in a material making the connection between work and everyday life?”

considered to be a useful category by the respondents, having a mean value of 4.2 and 76% answering 4 or 5. “Interviews with professionals” had a mean of 3.4 and 51% answered 4 or 5, and “List of occupations” had a mean rating of 2.9 and 34% answered 4 or 5. The lowest rated category was “Rationale from Skolverket” which had a mean of 2.4 and 14% answering 4 or 5.

In the questionnaire, the respondents were also asked if they had any suggestions of their own as to what kind of content the material should contain. These answers included: “*Experiments that makes the direct connection to everyday phenomena and everyday products*” (Experiments), “*Study visits to see processes and products that can be created with a background in chemistry*” (Study visits), “*Things happening in the world, that can be connected to chemistry*” (News), “*Current, applied research*” (Research) and “*Historical context*” (Historical events).

During the interviews, the teachers were asked to rank the usefulness of the four different categories found in the prototype, “Everyday phenomena”, “Everyday products”, “Historical events” and “News”, and a fifth category, “Interviews with professionals”. The ranking was made on a scale from 1 (Not useful) to 5 (Very useful). They were also asked to motivate their answers. In Figure 11, the result of all five categories can be seen. Below follows an in-depth presentation of the results of each category.

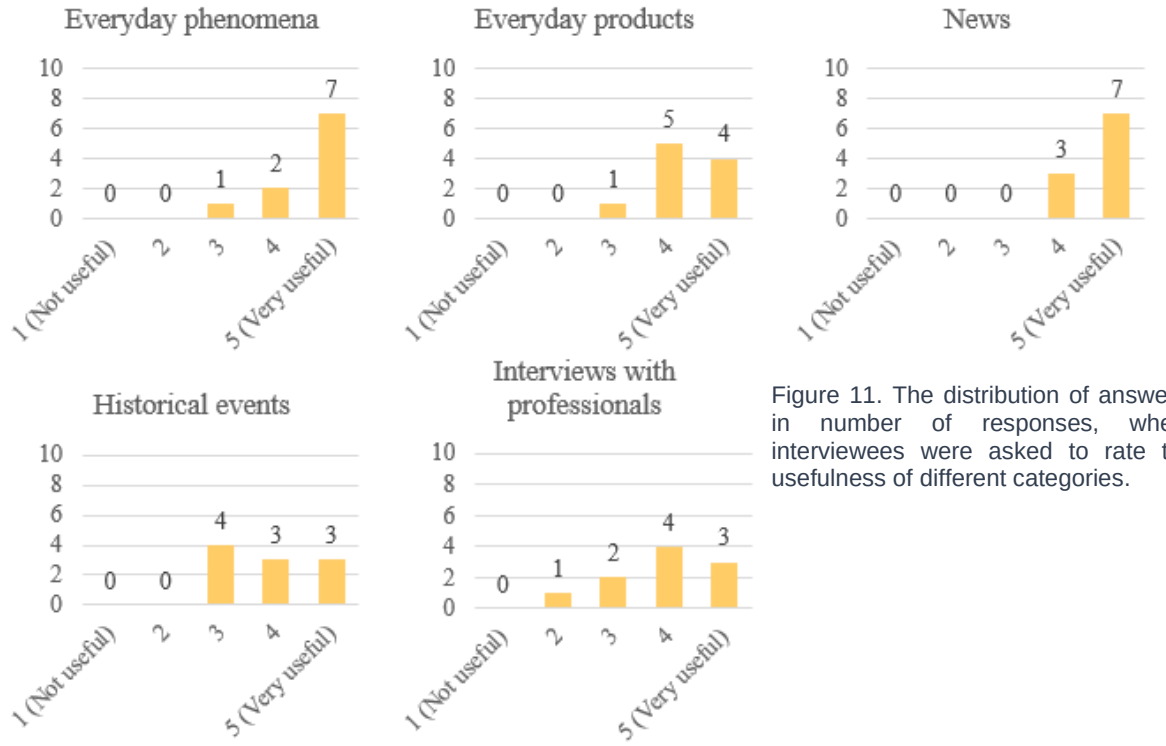

Figure 11. The distribution of answers, in number of responses, where interviewees were asked to rate the usefulness of different categories.

Everyday phenomena

The category “Everyday phenomena” was given a mean value of 4.6 by the teachers in the interviews. The distribution of answers can be seen in Figure 12. It was stated that this category is useful as it is easily relatable for the students; that examples of everyday phenomena are relevant for the students as individuals or the society in which they live, and that examples includes things that the students have all experienced or seen. Some of the teachers mentioned that this category is good for attracting interest as it concerns things that the students have experienced but previously not linked with chemistry, and that it exemplifies where chemistry is all around us. One aspect brought up during the interviews was that everyday phenomena examples often seem easy at first glance, but quickly can become rather complex and that teachers in the upper secondary school have to be able to focus more on the theoretical content of the material than in the lower grades.

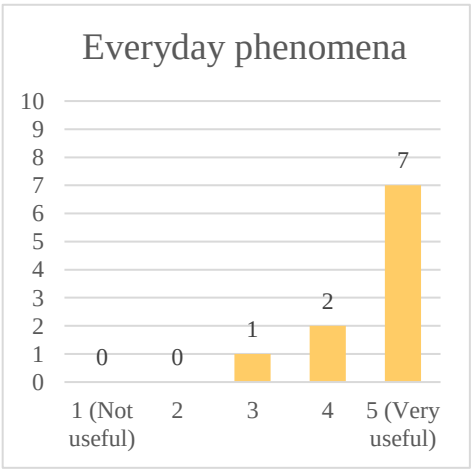

Figure 12. The distribution of answers, in number of responses, where interviewees were asked to rate the usefulness of the category "Everyday phenomena".

"[Everyday phenomena] *is just what I want, I want that close everyday connection. I think that this is what the students most easily can relate to. The whole idea with connections to everyday life is that the students feel that what I have to teach is relevant and interesting to them.*"

"[The category 'Everyday phenomena'] *is very useful to spark interest.* […] *It is easy for* [the students] *to connect to things happening in their lives, things they have experienced but maybe not seen from a chemical perspective before.*"

Everyday products

The category "Everyday products" was given a mean value of 4.3 by the teachers in the interviews and the distribution of answers can be seen in Figure 13. They attributed this category the same level of relevance to the students as "Everyday phenomena" and, in addition, it was said that it is good for the students to see what knowledge in chemistry can lead to. They expressed, however, that it is somewhat more limited than everyday phenomena due to the fact that the products have to be products that the students actually use and there is a great variation between what products different students use. One teacher stated that a positive aspect of this category was that the examples felt clearly connected with the theoretical content and, therefore, it did not feel forced to include them in their teaching.

Figure 13. The distribution of answers, in number of responses, where interviewees were asked to rate the usefulness of the category "Everyday products".

"[The category Everyday products are useful for] *knowing what you can use knowledge in chemistry for. Also, it is relevant as the products are in proximity to themselves* [the students], *there is a recognition factor.*"

"*Everyday products are somewhat limited to whether the students use the products or not. Batteries for example. Not everyone knows that much about batteries since, nowadays, you just put in your charger. There is not as much focus on the battery itself and how it works.*"

Historical events

The category "Historical events" was given a mean value of 3.9 by the teachers in the interviews, the distribution of answers can be seen in Figure 14. The general opinion of the teachers was that this is a good category for attracting interest, mostly for the students that already have an interest in history. One teacher stated that, even though the category's usefulness is limited to students with a previous interest, it is positive to include it in order to meet the needs for different students. In general, the teachers that gave a higher rating, also said that they found history interesting themselves, and vice versa. A couple of teachers also highlighted the fact that historical events can be used to examine one of the Abilities in the Chemistry curriculum, namely "Kunskaper om kemins betydelse för individ och samhälle" [Knowledge about the impact of chemistry on individuals and society]. This is an Ability that, according to the interviews, many teachers have trouble incorporating since they experience that a lot of the available time needs to go to the theoretical content and therefore there is often limited time to make connections to the impact on individuals and society.

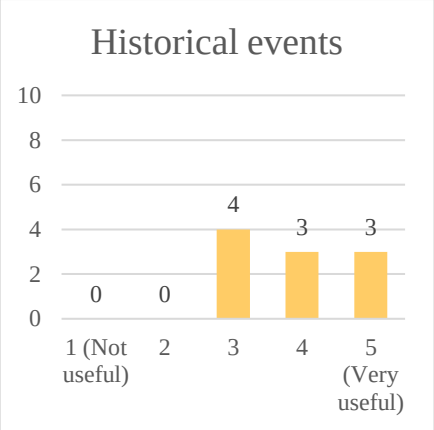

Figure 14. The distribution of answers, in number of responses, where interviewees were asked to rate the usefulness of the category "Historical events".

"*I think* [the category 'Historical events'] *could include fun anecdotes. I think that fewer students can relate to historical events* [than everyday phenomena- or products]. *But on the other hand, it could be needed since students are different and have different interests.*"

"*Really interesting category.* […] *There are many students who like history, so to attract interest you could definitely start an experiment or area with a historical event. I would definitely use this material as an engaging material. I will put a three on this one.*"

News

The category "News" was given a mean value of 4.7 by the teachers in the interviews, the distribution of answers can be seen in Figure 15. One advantage with this category, brought up in the interviews, was that news are good for making chemistry relevant for the students. News can show that chemistry actually is being used in today's society and that, what the students are being taught is applicable in current situations. Another advantage is that this category is connected both with the Aim of the subject and the Abilities in the Chemistry curriculum. As with "Historical events", the teachers felt that the usefulness of the News-category could be limited to students with an already existing interest. It was also stated that it is important to keep this category updated in order for it to stay relevant.

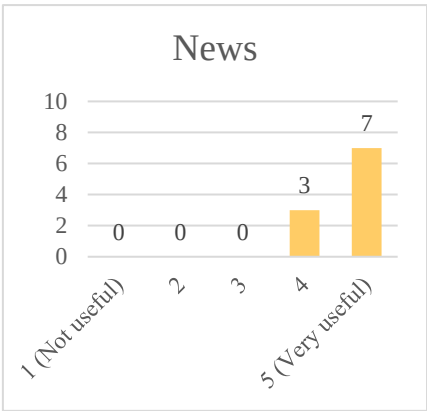

Figure 15. The distribution of answers, in number of responses, where interviewees were asked to rate the usefulness of the category "News".

"*Everything that is relevant with present day, I think is really important. It is something I use in my teaching, partly to raise engagement and interest, but also to show that this course* [the

chemistry course] *is 'for real'. Chemistry is not just something you learn in school but something that is going on in the rest of the world as well.* […] *So, it is important for the students to see that the knowledge in chemistry is applicable outside school as well.*"

"[The category 'News'] *is also very usable, however, it is something that needs to be updated to stay useful. Partly* [it is useful] *because this is something that is in the Subject curriculum, that you should try to connect things that are new in science in different ways, and establish this connection between science and what is happening.*"

"*Everyday phenomena- and products, they* [the students] *will come in contact with no matter what. Historical events and news, only if they have that specific interest.*"

Interviews with professionals

The category "Interviews" was given a mean value of 3.9 by the teachers in the interviews, the distribution of answers can be seen in Figure 1. During the interviews, it was stated that the students, and sometimes the teacher, have more focus on university studies than on work life, since that is in closer proximity to the students. It was also stated that some teachers experience a lack of possibilities to make connections to work life in the chemistry courses in upper secondary school. The teachers who were positive to this category stated that it would be good in order to show the students how chemistry is used in different people's professional everyday life, what kind of professions you could pursue, that there is more than one path to take after graduation, and to provide potential role models for the students. Another positive aspect of this category that was brought up during the interviews was that it is good for teachers to get insight in other chemistry professions, in particular teachers who have not themselves had another occupation. Examples of professions and workplaces that the teachers mentioned could be suitable are *Kemikalieinspektionen* [the Swedish Chemical Agency], *Arbetsmiljöverket* [the Swedish Work Environment Authority], different industries such as paper, wood and plastics, engineers, and scientists on different academic levels such as professors, post-docs, and PhD students. Another suggestion was made to include interviews with university students. The key, according to the teachers, is to have a great variety of people included in this category. One difficulty with this category, that was mentioned during the interviews, was that many occupations concern multiple aspects of chemistry, thus, it would be difficult to make the connection to one specific part of the Core content. Another difficulty that was mentioned was that because it is not as closely linked to the theoretical content as, for example "Everyday products", it felt difficult to fit into the teaching in a time-effective way.

Figure 16. The distribution of answers, in number of responses, where interviewees were asked to rate the usefulness of the category "Interviews with professionals".

"*I think* [the category 'Interviews with professionals'] *is interesting because you see what the knowledge can be used for, eventually.*"

"*You can show the students that there is more than one way to go.*"

”*It is good to have many different professions.* […] *if you were to find ten different people from ten completely different branches of industry and professions, that would be good. I believe in quantity here.*”

Other categories

During the interviews there were some other suggestions on useful categories. These were “Experiments”, “Cool stuff” and “Current research”. The teachers suggesting “Experiments” found the laboratory time to be a good forum for making the connections between the curriculum and work- and everyday life. This could be a category by itself or experiments could be included in the already existent categories. “Cool stuff” was suggested as an additional way to get the students attention and to raise their motivation. “Current research” was suggested to have similar advantages as “News” and “Interviews with professionals”, namely that the students can see what they can use their knowledge in chemistry for in the future, and to see that chemistry is important in today’s society.

During one of the interviews, it was stated that “*what is useful is variation*”, and that if the material would have included only one category it would be too limited. So, a variety of categories would be useful.

4.3.2. Other aspects concerning content

During the interviews, the teachers were asked about three different potential aspects of a material making the connection between the curriculum and work- and everyday life. The first was “Level of connection to sustainable development”, that is, how well the content is concerned with sustainable development topics. The second is “Level of comprehensiveness”, that is, how deeply does the material go into each example. The third aspect was “Level of concretion in the connection to the curriculum”, which is how straight forward the connection is between the theory, in an example, and what it says in the Core content.

Concerning “Level of connection to sustainable development”, the teachers were asked to what degree they find it important that this kind of material makes connections to sustainable development, on a scale from 1 (To a low degree) to 5 (To a high degree). The mean value of the answers was 3.3, and the distribution of answers can be seen in Figure 17. Most of the teachers interviewed said that sustainable development is important and that it is part of the curriculum for chemistry in Swedish upper secondary school. However, they also said that there is a lot to cover in the chemistry course, and therefore the connection to sustainable development should not be forced. If forced, they expressed a risk that the students would be confused or have trouble understanding the theory. One teacher said that the connection to sustainable development should be “*moderate but continuous.*”. In general, the teachers thought it would be good if the material made connections to sustainable development, so as to help teachers implement it in their

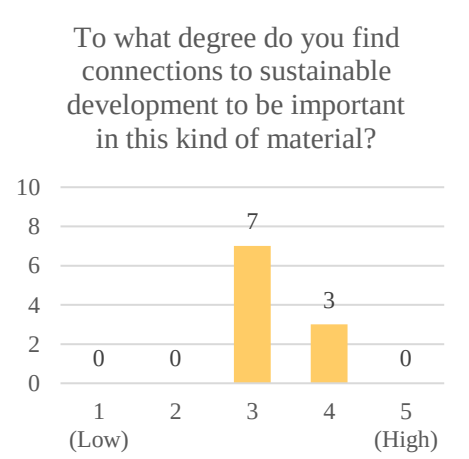

Figure 17. The distribution of answers, in number of responses, to the question "To what degree do you find connections to sustainable development to be important in this kind of material?"

classes, but the material would fulfil its purpose and be useful even without them. One suggestion was to mark relevant examples in the material with small icons from the global Sustainable Development Goals.

"*It is very clear in the curriculum that they want us to make these connections* [to sustainable development] *visible in the courses, so it is good if you can get help to do that.*"

"*I am quite neutral on this question, three out of five. Mostly because, if I were to ask the opposite - if there had not been a theme of sustainable development, I would not have thought 'Oh no, now it's not as good' or 'Now I can't use it'.* […] *As long as there is a connection* [to the curriculum]. *That I feel is more important than that connection being to sustainable development.*"

Concerning the "Level of comprehensiveness", the teachers were asked what level of detail they though this material should have, where one represented a "low" level of detail and five represented a "high" level of detail. The result was a mean value of 4.4, and the distribution of answers can be seen in Figure 18. There was some disparity in the teachers' opinions, depending on whether the material was to be used as a student material, or for the teacher only. If the teachers were to be the main user, there should be a high level of comprehensiveness. One teacher said that "*It saves me a lot of time, if someone else have done the work. Because it takes a lot of time to look for information and see 'is this relevant?'.* […] *A high level of comprehensiveness is a big help.*". Another stated that "*If it is something I understand better, I find it easier to be more enthusiastic.*". It was also stated that it is easier for teachers to adjust the information to their students if they themselves understand it better. If the material were to be used as a student material some of the teachers preferred shorter, less comprehensive versions of the examples in the material, as it would be easier for the students to assimilate the information without getting confused. However, the teachers noted that this can vary for different examples and different students. For example, some students that became interested in a particular example or needed more challenging texts had use for the more detailed versions as well. Some teachers stated that both a shorter, less detailed, version and a more detailed version of each example in the material was good to have as that gives the teacher the best basis for using what they see fit in their class.

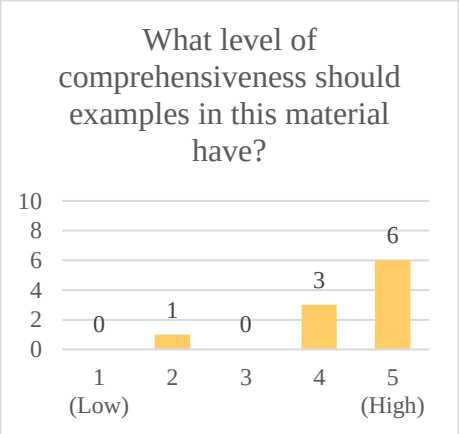

Figure 18. The distribution of answers, in number of responses, to the question "What level of comprehensiveness should examples in this material have?".

"*If it is for the teacher, it is good if* [the level of comprehensiveness] *is at level five but for the students it could, depending on the example, be enough with a level three or four.*"

"*I think it is great that there are two versions because then you can really tailor the content to what fits your group.*"

Concerning "Level of concretion in the connection to the curriculum" (how straight forward the connection is between the theory, in an example, and what it says in the Core content) the teachers in general thought that as long as there is some connection, and that the connection is clear, the level of concretion could be low. Some teachers also added that it could be positive

to have a low level of concretion because that would enable you to be more creative and the material to be "*more alive*". It was also said that "*If everything is only concretely connected, it is just like another textbook.*". One teacher stated that a high level of relevance to the students is more important than a high level of concretion. It was mentioned that it might be easier for the teacher to fit the content within his/her classes if it had a more concrete connection, but the same teacher also added that for the students, it would not matter. Once again it was brought up that a mix would be great, because then the teacher could more easily adjust the content to their particular class.

"*As long as you start somewhere so that you get a 'chemistry angle'* […]. *A lot of students see chemistry as something that there is no use for at all, or at least very little. So, every tip is good, so you can get that 'Aha, this is actually used there' and 'It was good to know this'.*"

"[The level of concretion] *doesn't always have to be high. However, there has to be some common ground and the teacher should be able to find 'natural steps' that motivates why the example is included.*"

During the interviews, several other aspects, that were not asked about specifically, were brought up by the teachers. Some teachers found the examples in the prototype to lack connections with work-life. It was stated that one way to add this is through the category "Interviews with professionals" but it was also suggested to include connections to work-life continuously in the examples throughout the material and include examples with a clearer work-life connection. The connection to work-life was said to be specifically important for students in the Technology program, since those students in general are not as inclined to pursue further studies in chemistry as students in the Nature science program.

The matter of experiments was brought up in both the questionnaire and the interviews. During the interviews it was suggested to include tips on experiments in each example, either as a full experiment manual or as short descriptions and then links to another page with the full manual. The teachers suggesting this stated that experiments are a good forum for making the connection between the theory and work- and everyday life. One teacher wished for experiments that the students could carry out at home.

Another thing that some of the teachers wanted to include in the examples in the material was exercises. The different types of exercises brought up during the interviews were short theory questions, larger discussion exercises and reflection exercises. The teachers that suggested this stated that using exercises is a good method for engaging students with the material and making them more active. However, creating these exercises takes a lot of time, which the teachers might not have.

Some of the teachers mentioned that so called "clickbait" captions could be useful for attracting the student's interest. This could be done by using examples with large numbers or spectacular questions.

Lastly, another advice regarding content was to include some suggestions as to how the material could be used by the teachers. This could be done by including different lesson-designs in which the material is integrated.

4.3.3. Discussion of ”Content”

Regarding the result from the questionnaire concerning which categories the respondents would find useful in a material making the connection between the curriculum and work- and everyday life, getting a mean value higher than three can arguably be considered as “useful”. A mean value of 3 would indicate that the respondents found the category neither useful nor not useful, thus, anything above 3 would indicate that the category would be useful, at least to some extent.

In the questionnaire, the lowest ranked alternatives were “List of occupations”, with a mean value of 2.9, and “Rationale from Skolverket”, with a mean value of 2.4. Thus, these two categories were not considered useful, and neither was included in further testing through the prototype and user test. It is interesting that, once again, *Skolverket* is rated at a low level. Earlier it was stated that one explanation for *Skolverket*’s low mean values could be because what was asked about did not fit the purpose of *Skolverket*. However, in this case the question concerns the rationale for what is included in the curricula, which falls under the purpose of *Skolverket* as stated in section 2.1, and still, the teachers would not find it useful to know the rationale behind these decisions. Is this because the teachers are not familiar enough with the tasks of *Skolverket*? Do they not think that the rationale from *Skolverket* would be relevant to the students? Or is there some other reason entirely? This would be interesting to explore further but falls outside the scope of this study.

The categories “Everyday phenomena”, “Everyday products” and “Interviews with professionals” each scored mean values higher than 3 in the questionnaire, thus indicating that the teachers would find them useful as categories in a material making the connection between the curriculum and work- and everyday life. All three categories then scored higher than 3 in the interviews following the user test as well, thus repeating the result of these categories being useful. The categories “Historical events” and “News”, which were given as text answers in the questionnaire, both scored mean values higher than 3 in the interviews, therefore indicating that the teachers would find them useful as well in a material making the connection between the curriculum and work- and everyday life.

One could argue that, in order to develop the most useful material, one should include only the categories rated the highest regarding usefulness. However, both in the comments on the category “Historical events” and in the comments on the categories in general, the interviews showed that there is value in having a variety of categories. This is also supported by Bolte et.al. (2013), who state that one strategy for stimulating motivation is to vary the learning environment. By including all categories, that the respondents to the questionnaire and the teachers in the interviews thought to be useful (that is, scoring above 3), the material could help teachers vary their teaching and thereby facilitate motivation.

Other potential categories mentioned in the text answers in the questionnaire were “Study visits”, “Research” and “Experiments”. The authors of this study deemed “Study visits” to be outside the scope of the material because it would require adjusting the material to different geographical locations. For instance, the possible locations for study visits differ between Stockholm and Gothenburg. However, since the respondents in the questionnaire brought it up as something that would be useful for making the connection between the curriculum and work- and everyday life, a potential expansion of the material could be to include study visits. However, further studies would be needed to investigate how this would be done. The potential

category “Research” was also suggested in the interviews. As stated in the interviews, “Research” was considered to have similar advantages as the categories “News” and “Interviews with professionals”. The authors, therefore, believe that the category “Research” could fit into these, already existing categories. The category “Experiments” was after the questionnaire deemed by the authors to be outside the scope of the material and its purpose and was therefore not included in the prototype. The reason was mainly because experiments were considered to be complete lesson plans, and therefore difficult to adjust to different teacher’s lesson plans. The thought with the material was that it should be up to the teachers how to implement it in their teaching. “Experiments” was also mentioned during the interviews where many of the teachers, however, expressed that laboratory time is a suitable occasion for making the connection between the curriculum and work- and everyday life and that they lacked “Experiments” in the prototype.

Apart from “Research” and “Experiments” the category “Cool stuff” was mentioned, with the motivation that it is a good way to spark the student’s interest. Whether this category fit in the material or not, the authors find is dependent on how you interpret the purpose of the material. On one hand, it is said that the material should contain connections between the curriculum and work- and everyday life. “Cool stuff” are not concrete examples of work- or everyday life and could therefore be considered not to fit in the material. On the other hand, the purpose of the material is to help teachers motivate and engage their students, in which case “Cool stuff” would fit well.

Many of the teachers mentioned during the interviews “the student’s interests”, for example when discussing which categories are the most useful. Deci and Ryan (2000) also talk about interest, and the necessity of feeling interested in order to develop an intrinsic motivation. This refers to individual interest, or topic interest. As stated in section 2.3, Bolte et.al. (2013) mean that reoccurring situational interest can lead to the development of individual interest. If the material could contain varying categories and examples, as suggested in the interviews, the material would have a larger potential to meet each student’s individual- or topic interest and/or spark the student’s situational interest enough times for them to develop a more long-term interest. Thereby, the material would reach the purpose of motivating and engaging the students.

Apart from the importance of variation, the teachers also stated that the material need to be adjusted to the students, both concerning language and content. For example, the examples need to be updated so that the students can relate to them. Koballa and Glynn (2007) describe how interest can fade if the activity becomes associated with too many negative factors. Bolte et.al. (2013) mention the level of difficulty and the level of enjoyment as factors that could become negative. So, the choice of content does not only affect the possibility to spark interest, but also to maintain interest. Thus, when choosing which examples to include in the material it is important to take into consideration what the students find interesting, to adjust the language, and to make sure there is content that fit many different students. One example of a study, that could be used in the purpose of deciding on content, is the ROSE-study (Schreiner & Sjøberg, 2010) mentioned in section 2.5.

Concerning the other aspects, apart from the categories, explored in the interviews, the connection to sustainable development was interesting because it is closely linked to the curriculum. As many teachers stated in the interviews, it is important to connect the teaching

at upper secondary school to sustainable development and yet, it was not given a higher mean value than 3.3. This is interpreted as important, but still quite close to neutral. This result indicates that a connection to sustainable development is not considered important by the teachers in order for the material to fulfil its purpose. The impression from the interviewed teachers was that sustainable development is seen as "an obligation", which of course is important, but not necessarily something that is easy to fit within their teaching. Considering this difficulty and the fact that sustainable development is anchored in the curriculum, it would be recommended to include connections to sustainable development in the material. Furthermore, in the ROSE study it was shown that many students found sustainable development to be interesting (Schreiner & Sjøberg, 2010). Thus, connections to sustainable development could help motivate the students.

Concerning the aspect "Level of comprehensiveness", which was given a mean value of 4.4, where a 5 represented a "high" level of comprehensiveness, it seems clear that the teachers prefer the material to be detailed. The main reason was so they themselves can read up on the subject without having to spend time on research and screen for relevant information. The suggestion to include both a comprehensive version and a less comprehensive version of the examples, as in the prototype, was interesting as it was motivated by the teacher's wish to be able to adapt the material to their particular class and lesson plan. The same motive has been discussed above concerning variety of categories and examples and it is also mentioned in the interviews when talking about the "Level of concretion in the connection to the curriculum". In order to get the most out of the material, it seems that it has to be flexible so that each teacher can tailor what they use to their class. To adjust the material for each group of students fits well with the theory that the difficulty level needs to be just right for the students to feel motivated (Bolte et.al., 2013). The suggestion to include examples of lesson-designs and other ways to use the material could help teachers save time and make use of the material. However, in order to keep the flexibility, it is important to make it clear that such examples would only be suggestions and that the teachers are free to use the material as they see fit.

In general, the interviewed teachers though that the "Level of concretion in the connection to the curriculum" could, or should, be low. One reason for this was to make the material more alive for the students and it was indicated that current textbooks do not include exiting examples of situations where chemistry can be seen in the students' everyday lives. This could suggest that most textbooks for upper secondary chemistry in Swedish has a Vision I of scientific literacy. This is interesting because, as stated in section 2.5., curricula in general are moving towards Vision II.

One suggestion of things to include in the material was exercises. This could help teachers and students to take on a deep approach to learning. As stated in section 2.2, one strategy for helping the students achieve deep learning, according to Smith and Colby (2007), is to guide them to ask reflective questions about what is being learned, to take a deep approach to learning. By including reflective exercises and more implications in the examples, the material could help the teachers do this. The exercises would, in addition, make the material more versatile.

4.4. Discussion of method

A few comments should be made concerning the methods chosen in this study. Firstly, when conducting the literature review, the references found were documented in a list in order to have structure. In hindsight, it would have been more systematic to do a more comprehensive and organized literature review, for example by documenting search strategies, in order to minimize the risk of missing relevant references.

Further on, the questionnaire was only emailed to teachers in the three most populated regions of Sweden. This was assumed to be a representable sample frame when in reality there could be differences between teachers in regions of various population density. For example, chemistry teachers in less populated areas might have fewer chemistry teacher colleagues in the area to exchange ideas with than chemistry teachers in more populated areas. These kinds of differences were not taken into account when this study was performed. The fact that the survey was posted in an online forum for Swedish chemistry teachers might have evened out the differences to some extent, but whether this is the case cannot be proven since respondents were not asked where they work.

Another problem with the sample frame is that people who decided to respond, and especially sign up for the user test, might have done so because they already have a positive mindset towards the idea of the study. Thus, for example, results about teachers' attitude towards connecting the curriculum with work- and everyday life might not be representable to all Swedish upper secondary school chemistry teachers. This problem is reoccurring in every study that bases participation on voluntariness. Changing that condition would be difficult though with respect to the ethical perspective.

As always when a self-administered questionnaire is used, it is not certain that the questions are interpreted as the researchers intended, what Esaiasson et.al. (2017) calls construct validity. One reason for this could be that respondents sometimes skip the introduction where important terms and ideas are defined or that the researchers missed something when designing the questions for the data collection. Such misunderstandings could be caught in the interviews, where there was a greater possibility for the respondents to elaborate their answers and the researchers to ask follow-up questions. This would indicate that the responses from the interviews probably are more reliable than the ones from the questionnaire. However, not all questions from the questionnaire were brought up during the interview so the potential problematics regarding construct validity could remain with some of the questions.

Regarding the user tests, neither instructions on how to use the material nor what questions were to be discussed during the interview were given at the start of the user test. This was a deliberate choice of method, in order to steer as little as possible so that the teachers would use the material as they saw fit. However, perhaps more thoughtful answers could have been given in the interviews if the interviewees would have seen the questions before the interviews. One possible solution to this could have been to send out the questions a few days before the interviews.

One question is whether or not theoretical saturation has been achieved, that is, whether or not all relevant aspects of the teachers' views on the research questions have been identified (Esaiasson et.al., 2017). It could be argued that theoretical saturation has not been completely achieved, firstly because of the issues regarding sample frame discussed above, and secondly

because new information was presented during all interviews. However, the larger traits of the responses were recurring in most of the interviews, thus, the data collection was still assumed to be sufficiently comprehensive to draw conclusions.

4.4.1. Recommendations for further research

The aim of this thesis was to develop the prerequisites for a material connecting the curriculum for Swedish upper secondary school chemistry with work- and everyday life. After concluding the study, a number of recommendations can be made regarding these prerequisites but there are also some recommendations to be made regarding further research. First, regarding the platform, there is a difference if the material is to be a freely accessible material, or a material to be paid for. The latter could be the case if the material is distributed by a company such as, for example, a teaching aid manufacturer. The implications of it being a material the schools need to pay for has not been investigated in this study but would be useful to explore further in order to know the necessary conditions for the distribution of this material.

Secondly, regarding the possible content of the material, a suggestion brought up in the questionnaire was "Study visits". This was thought to be outside the scope of this study, but it would be interesting to explore further how "Study visits" could be incorporated in the material since the teachers seemed to be interested.

As stated in section 1.4., the students' point of view and the possible consequences this material could have on learning outcomes have not been investigated in this study. If the material were to be developed in full, these are aspects that would be interesting to look at, in order to see the actual outcome of the material.

Another suggestion for further studies is to verify the results from this study. This could be done by collecting data from more teachers in order to reach a higher representability and ensure theoretical saturation and/or to design experiments that could verify the results from this study statistically. The methods used in this study results in the possibility to make suggestions and see indications towards what the teachers think but to be sure, the results would need to be statistically validated.

The aim of this study could be carried out with other courses than Chemistry 1 in mind. In this study there was a focus on the course Chemistry 1 since the prototype was based on the Core content for Chemistry 1. The assumption was made that many of the conclusions could be generalized for chemistry as a subject. However, some things brought up during the data collection, for example the large amount of theoretical content that need to be covered, concerns mainly Chemistry 1. It would therefore be interesting to explore further regarding other courses such as Chemistry 2 or *Naturvetenskaplig specialisering* [Nature science specialization]. In addition, the concept of this material could be expanded to include other subjects than chemistry, for which additional research would be necessary.

In the discussion of content, two aspects which regards the teachers' views were brought up that fell outside the scope of this study but would be interesting to explore further. The first was the teachers' attitude and approach to sustainable development in their teaching. Even though sustainable development is a central part of the curriculum for upper secondary school, and the subject chemistry, teachers seemed to have a negative attitude towards incorporating sustainable development in their teaching. In order to ensure that sustainable development takes

a natural part in Swedish education, this perceived poor attitude would be interesting to research. Perhaps a material such as the one explored in this thesis can be a tool in making it easier and more enjoyable for the teachers to incorporate sustainable development in their teaching. The other aspect was the teachers' view on *Skolverket*. There were indications during this study that the teachers might not think that highly of *Skolverket* as a provider of teaching aid. This is something that could undermine the task of *Skolverket* and would therefore be interesting to investigate further.

Lastly, in this study it appeared as if Swedish textbooks for chemistry education to use in upper secondary school has a prominent Vision I of scientific literacy. Since reviews of textbooks were not included as a part of this study and since curricula are moving towards Vision II, to investigate this further could make a valuable contribution to the field.

5. CONCLUSIONS

The purpose of this study was to answer the question *"What aspects are of importance when developing a material of connections between the curriculum and work- and everyday life for chemistry teachers to use in Swedish upper secondary schools?"*. This question was divided into four sub-questions. In this final section these will be answered briefly on the bases of the findings of the study.

- To what extent do chemistry teachers experience existing material to fulfil the purpose of making the connection between the curriculum and work- and everyday life?
  - This study suggests that for most Swedish chemistry teachers in upper secondary school, there is no source, that they know of, that makes the connection to work- and everyday life in satisfactory way.

- To what extent do chemistry teachers experience a need for a material making the connection between the curriculum and work- and everyday life?
  - This study suggests that there is a widespread need for a material making the connection between the curriculum and work- and everyday life among Swedish chemistry teachers in upper secondary school.

- What kind of format and platform would be suitable for a material with the purpose of making the connection between the curriculum and work- and everyday life?
  - This study suggests that this kind of material would serve its purpose best as a web-based material due to what features could be included.
  - This study suggests that the material should have the following features:
    - Links to references and further reading, since that shows that the information is reliable and the teachers and/or students can read more if needed.
    - Downloadable illustrations, animations, and videos to help clarify the theory in the different examples.
    - A search function and, for example, clickable menus to make the material easy to navigate.
  - This study suggests that *Kemilärarnas Resurscentrum* [Chemistry Teachers' Resource Center] (KRC) would be a suitable platform for this kind of material, since it is a website known and used by many chemistry teachers.

- What kind of content would teachers find useful in a new material with the purpose of making the connection between the curriculum and work- and everyday life?
  - This study suggests that the material should include examples from the following categories:
    - "Everyday phenomena", since it relates chemistry to the students' everyday by linking school chemistry to experiences the students have had.
    - "Everyday products", since it relates chemistry to the students' everyday life by linking school chemistry to products the students have seen or used.
    - "News", including current research, since it shows what chemistry can be used for and is relevant in today's society.

    - "Historical events", since some students have an interest in history which could be used to make school chemistry more interesting to them.
    - "Interviews with professionals", since it shows what chemistry can be used for and makes connections to work-life.
- This study suggests that the material should include experiments connected to the different parts of the Core content, either as a separate category or included continuously in the other categories.
- This study suggests that it is important to have variety in the examples and categories included in the material in order to appeal to many different students and vary the teaching.
- This study suggests that the examples in the material should:
    - Have a clear, but not necessarily concrete, connection to the curriculum.
    - Make connections to sustainable development when that connection is relevant to the example.
    - Make connections to work life, when possible.
    - Be updated to suit the students, both in topic, language and in level of difficulty.
    - Have a high level of comprehensiveness in order for the teachers to be able to familiarize themselves with the examples. The material could include a less comprehensive version as well in order to make it easier for the teachers to adapt the material to their students.
- This study suggests that the examples in the material could include exercises, both reflection-, discussion- and shorter theory questions, in order to make the material more versatile.

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APPENDIX A. THE QUESTIONNAIRE

In this appendix the self-administered questionnaire is presented as seen by the respondents, including the instructions. The full questionnaire was not visible simultaneously, but one section at the time. At the press of the button “Nästa” the respondent was directed to the next section.

Undersökning av behovet av ett nytt inspirationsmaterial för kemilärare

Hej och stort tack för att du valt att bidra till vårt examensarbete!

*Obligatorisk

Vad bidrar du till?

En utmaning som lärare står inför är att få de olika delarna av det centrala innehållet att kännas meningsfulla för eleverna.

Målet med vårt examensarbete är att undersöka önskemål och förutsättningar för ett material/idébank som kopplar det centrala innehållet i kursen Kemi 1 med arbets- och vardagslivet. Materialet ska fungera som en hjälp för lärare i uppdraget att motivera och engagera sina elever genom att vara ett verktyg vid till exempel lektionsplanering. Helt enkelt hjälpa lärare att besvara elevfrågan "Varför ska jag lära mig det här?".

Den här enkäten är det första steget i undersökningen av hur ett sådant material bör se ut och var det bör finnas för att vara så användbart och tillgängligt som möjligt. Enkäten består av 3 delar som behandlar behov, existerande material och det nya materialet. Enkäten tar ca 10 minuter att genomföra.

Resultatet från enkäten kommer att leda till utvecklingen av en prototyp av det här materialet. Den prototypen kommer vi sedan vilja testa bland er kemilärare. Skulle du kunna vara intresserad av att delta, följ länken här:
https://forms.gle/xF63eMrKRrnfnzhY9
(Mer information finner du i slutet av enkäten)

Du som svarar kommer att vara anonym och i resultaten kommer det inte att framgå vad en enskild person har svarat. Efter sammanställning kommer samtliga svar att raderas, senast 1 september.

Stort tack och har du frågor, tveka inte att höra av dig till oss!
Johannes Nordberg (johanord@student.chalmers.se)
Nina Franzén (fnina@student.chalmers.se)

Fråga 1: Jobbar du/har du jobbat som gymnasielärare i kemi under de senaste 5 åren? *

- ◯ Ja
- ◯ Nej

Nästa

Behov

För att få grepp om hur vi ska få det nya materialet att bli så användbart som möjligt behöver vi veta hur behovet ser ut.

Fråga 2. I vilken grad upplever du att kopplingen mellan det centrala innehållet och arbets- och vardagslivet bidrar positivt till undervisningen? *

	1	2	3	4	5	
I låg grad	○	○	○	○	○	I hög grad

Kommentera gärna ditt svar på Fråga 2.

Ditt svar

Fråga 3. Upplever du att det är lätt eller svårt att göra kopplingar mellan det centrala innehållet och vardags- och arbetslivet som är relevanta i din undervisning? *

	1	2	3	4	5	
Lätt	○	○	○	○	○	Svårt

Kommentera gärna ditt svar på Fråga 3. Varför tycker du att det är lätt/svårt?

Ditt svar

Fråga 4. Har du i dagsläget tillgång till något material som fyller syftet att koppla det centrala innehållet till arbets- och vardagslivet? *

- ◯ Ja
- ◯ Till viss del
- ◯ Nej

Om du angett "Ja" på Fråga 4, vilket material syftar du på?

Ditt svar

Om du angett "Till viss del" eller "Nej" på Fråga 4, upplever du ett behov av ett sådant material?

- ◯ Ja
- ◯ Nej
- ◯ Vet ej

Kommentera gärna ditt svar på Fråga 4.

Ditt svar

Existerande material

Ingen ska behöva återuppfinna hjulet. Genom att undersöka existerande material hoppas vi kunna anpassa det nya för att så bra som möjligt täcka det behov som finns.

Fråga 5: I vilken grad upplever du att existerande material uppfyller syftet att koppla det centrala innehållet till arbets- och vardagslivet? *

	1 (I låg grad)	2	3	4	5 (I hög grad)	Ingen uppfattning
Kemilärarnas resurscentrum (KRC)	○	○	○	○	○	○
Magnus Ehinger	○	○	○	○	○	○
Skolverket	○	○	○	○	○	○
Youtube	○	○	○	○	○	○
PHET	○	○	○	○	○	○
Facebook	○	○	○	○	○	○
Royal Society of Chemistry (RSC)	○	○	○	○	○	○
Egen bank med material	○	○	○	○	○	○
Annat	○	○	○	○	○	○

Kommentera gärna ditt svar på Fråga 5. Om du angett Youtube/Facebook/Annat, specificera gärna. T.ex. namnet på en youtubekanal eller en facebookgrupp.

Ditt svar

Fråga 6: Hur hittade du till det material du använder i planeringen av din undervisning idag? *

- [ ] Google-sökningar
- [ ] Via tips från kollegor
- [ ] Genom online-forum
- [ ] Via Skolverket
- [ ] Via läromedelstillverkare
- [ ] Via en annan, för mig redan känd resurs
- [ ] Inget av ovanstående
- [ ] Övrigt: _____

Kommentera gärna ditt svar på Fråga 6. Om du har angett online-forum, specificera gärna.

Ditt svar

Bakåt Nästa

Nytt material

Till sist: Vad borde ett material med syfte att koppla samman det centrala innehållet i Kemi 1 med arbets- och vardagslivet innehålla? Besvara frågorna nedan och lägg gärna till egna förslag!

Fråga 7: Hur användbara hade du tyckt att följande alternativ var i ett material med syftet att koppla det centrala innehållet till arbets- och vardagslivet? *

	1 (Inte användbart)	2	3	4	5 (Mycket användbart)	Ingen uppfattning
Intervjuer med yrkesverksamma	○	○	○	○	○	○
Lista på yrken	○	○	○	○	○	○
Motivering från Skolverket	○	○	○	○	○	○
Beskrivning av vardagsfenomen	○	○	○	○	○	○
Beskrivning av vardagsprodukter	○	○	○	○	○	○

Har du några andra förslag på innehåll som du skulle finna användbart i ett material med syfte att koppla det centrala innehållet till arbets- och vardagslivet?

Ditt svar

Kommentera gärna ditt svar på Fråga 7.

Ditt svar

Fråga 8: Finns det något mer du vill lägga till?

Ditt svar

Delta i test av prototyp?

Resultatet av den här enkäten kommer att leda till utvecklingen av en prototyp som vi vill att ni kemilärare ska få testa att använda under några veckor! Syftet med prototyptestet är att ytterligare fördjupa insikterna kring materialets utformning för att maximera användbarheten. Om du kan tänka dig att ställa upp skulle det kortfattat innebära att:
- Du får tillgång till prototypen under ca 4 veckor i mars-april
- Du får använda prototypen på precis det sättet du tycker fungerar bäst
- Du ställer upp på en intervju någon gång ca vecka 15-16

Skulle du kunna vara intresserad av att delta i denna djupare studie? Fyll i dina kontaktuppgifter via länken som dyker upp då du skickat in enkäten, så kan vi berätta mer!
Du hittar även länken i utskicket som du fick enkäten i.

APPENDIX B.
THE INTERVIEW QUESTIONS

Here follows the questions which was the basis for the semi-structured interviews and the survey questions which was seen by the interviewee on the interviewer's shades screen.

B.1. Interview guide

Tema 1 – Intro

Beskriv dig själv och din yrkesroll

Intro/bakgrund

- Undervisar du för tillfället i Kemi 1?
- Har du undervisat om Syror och baser/Redoxkemi under tiden du haft tillgång till prototypen?

Tema 2 – Intressanta aspekter (RQ4)

Beskriv hur du har använt prototypen

- Vid vilka tillfällen? (Planering/i klassrummet)
- När i planeringen? (som inspiration/som material)
- När på lektionen? (Uppstart/när en elev frågar/i slutet av en genomgång)
- Vad gjorde att du använde det just så/just det exemplet/vid det tillfället?

Var det något du saknade i prototypen?

- Beskriv hur du hade velat kunna använda materialet?
- Hade du föreställt dig något annorlunda?
- Upplevde du någon begränsning i materialet?

Hållbar utveckling – På en skala från 1 till 5, hur stor vikt lägger du vid att materialet (i sin helhet) gör kopplingar till hållbar utveckling?

- Beskriv hur du tänker
- Hur tydliga kopplingar tycker du bör göras?
- Hur många kopplingar tycker du bör göras?

Översiktlighet – På en skala från 1 till 5, hur djupgående bör materialet vara enligt dig? (olika exempel från prototypen)

- Beskriv hur du tänker
- ”Under vilka villkor?”
- Exempel från prototypen:
    - Översiktligt – Alla s.k. Version 1
    - Djupgående – Alla s.k. Version 2

I vilken utsträckning använde du dig av länkarna i prototypen?

- Varför/varför inte?

- Hade du saknat de om de inte fanns med?
- Hade du velat ha fler länkar?

Konkret koppling? – Kopplingen till det centrala innehållet kan vara mer eller mindre konkret, beskriv hur du upplever användbarheten beroende på hur konkret kopplingen är.

- Exempel från prototypen:
  - Konkret koppling – ”Magsyra och buffert i magen” (s. 4)
  - Mindre konkret koppling – ”Varför gråter vi av att hacka lök” (s. 1-3)

Tema 3 – Kategorierna (RQ4) - 15 min

Berätta hur du upplevde de olika kategorierna (vardagsfenomen, vardagsprodukter, historiska händelser och nyheter)

Öppet börja diskutera vad de tyckte à se vad de verkar tycka var viktigt

- Vad var det som gjorde det användbart eller inte?
- Vad gjorde specifika exempel användbara eller inte?
- Ev påminna om kategorier som inte nämns

Vardagsfenomen – På en skala från 1 till 5, hur användbar (för syftet) **upplevde du kategorin Vardagsfenomen?**

- Beskriv hur du tänker

Vardagsprodukter – På en skala från 1 till 5, hur användbar upplevde du kategorin Vardagsprodukter?

- Beskriv hur du tänker

Historiska händelser – På en skala från 1 till 5, hur användbar upplevde du kategorin Historisk händelser?

- Beskriv hur du tänker

Nyheter – På en skala från 1 till 5, hur användbar upplevde du kategorin Nyheter?

- Beskriv hur du tänker

Om materialet hade innehållit en kategori med intervjuer med yrkesverksamma, vad tror du om det? Beskriv hur du tänker.

- Beskriv hur du tänker

Något du vill lägga till angående innehållet?

- Ex någon kategori som vi inte haft med men som du tänkt på

Tema 4 – Plattform (RQ3) - 25 min

Vi lämnar innehåll och prototypen och går över på format och plattform. Om materialet fanns i sin helhet:

Om du får tänka helt fritt, vilket format skulle du vilja att materialet hade?

- Hur bör det se ut?

- Vilka funktioner bör finnas?
- Hur sortera?

Vad tror du är avgörande faktorer för att materialet ska hittas och bli använt? (inte hamna på hög, oläst)

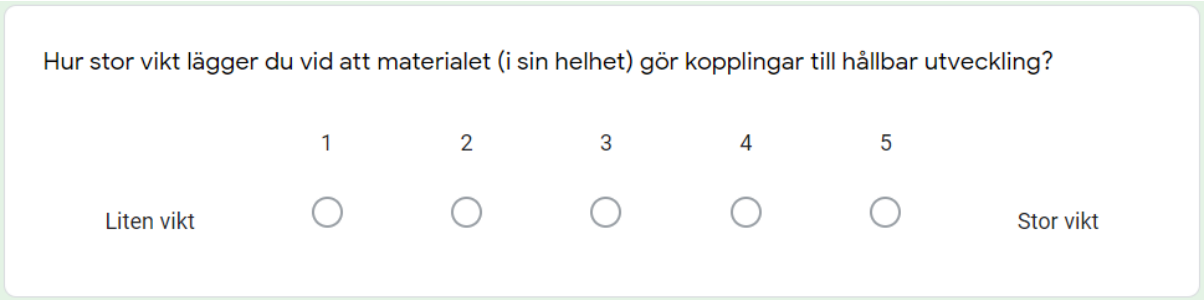
- Var borde det finnas för att DU ska hitta och använda det?
- Var borde det finnas för att LÄRARE ska hitta och använda det?

Tema 5 – Avslutning

Vill Johannes lägga till något?
Finns det något du vill lägga till?
Kan vi kontakta dig igen om det dyker upp frågor?
Info om var resultatet kommer presenteras
Vill du få tillgång till rapporten?
Stort tack!!

B.2. The survey questions for the interviews

The questions shown to the interviewee when asked to answer an a scale between 1 and 5.



Hur användbar upplever du kategorin "Vardagsprodukter"?

	1	2	3	4	5	
Inte användbar	○	○	○	○	○	Mycket användbar

Hur användbar upplever du kategorin "Historiska händelser"?

	1	2	3	4	5	
Inte användbar	○	○	○	○	○	Mycket användbar

Hur användbar upplever du kategorin "Nyheter"?

	1	2	3	4	5	
Inte användbar	○	○	○	○	○	Mycket användbar

Hur användbar tror du att en kategori med "Intervjuer med yrkesverksamma" hade varit?

	1	2	3	4	5	
Inte användbar	○	○	○	○	○	Mycket användbar

APPENDIX C. THE PROTOTYPE

Here follows the prototype material which the teachers who participated in the interviews has access to for five weeks.

Kemi 1 – Koppling mellan det centrala innehållet och arbets- och vardagslivet

En prototyp av ett material för kemilärare

Del av masterexamensarbete vid Lärande och ledarskap

Nina Franzén

Johannes Nordberg

AVDELNINGEN FÖR VETENSKAPENS KOMMUNIKATION OCH LÄRANDE

CHALMERS TEKNISKA HÖGSKOLA

Göteborg, Sverige 2021
www.chalmers.se

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Syror och baser

I det centrala innehållet i ämnesplanen för kemi i gymnasieskolan står det att undervisningen ska behandla reaktioner och förändringar som

”*Syrabasreaktioner, inklusive pH-begreppet och buffertverkan.*” [1].

Nedan följer exempel på vardagsfenomen, vardagsprodukter, historiska händelser och nyheter som behandlar ovan del av det centrala innehållet.

Vardagsfenomen

Varför gråter vi av att hacka lök? (Version 1)

När man hackar lök så förstör man lökens celler. Då cellerna går sönder reagerar vissa enzymer i löken och bildar gasen syn-propantial-S-oxid. Då gasen når ögat irriteras fria nervändar i ögat så att tårar framkallas. Då syn-propantial-S-oxiden löser sig i tårvätskan så bildas svavelsyra (H_2SO_4) som är det som stinger och fräter i ögat [2].

Läs mer på:

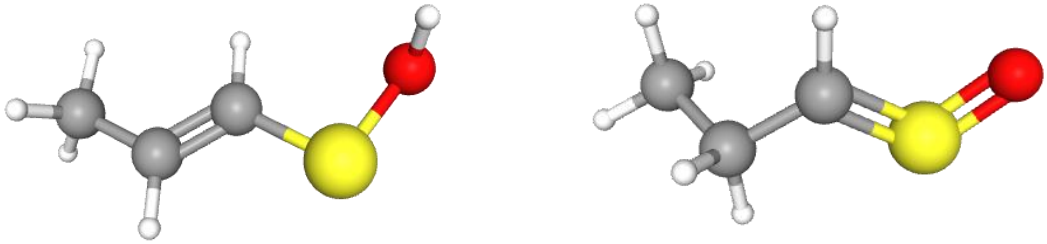
Skolkemi, Umeå – Experiment: Varför svider det i ögonen när man skalar lök?

Royal Society of Chemistry - Education in Chemistry: Magnificent molecules - Propanethial-S-oxide

Varför gråter vi av att hacka lök? (Version 2)

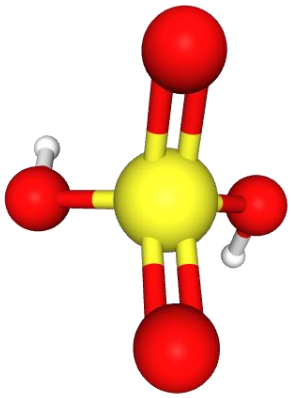
När man hackar lök så förstör man lökens celler. Ifrån vakuolerna i cellerna kan då ett enzym som kallar för alliinas frigöras [2]. Alliinas katalyserar en reaktion mellan vatten och S-1-propenyl-L-cystein-sulfoxid, också kallad isoalliin, som också finns i löken. En av produkterna i denna reaktion är 1-propenyl sulfensyra som syns i Figur 1a) nedan [5]. Med hjälp av enzymet *Lachrymatory-factor synthase* reagerar sedan 1-propenyl-sulfensyra vidare och bildar gasen syn-propantial-S-oxid som syns i Figur 1b) nedan [5].

a) b)



Figur 1. a) Strukturformel för 1-propenyl-sulfensyra som bildas då lökens celler förstörs. Från [3]. b) Strukturformel för syn-propantial-s-oxid, en gas som frigörs då man hackar lök och som irriterar ögat. Från [4].

Då syn-propantial-S-oxid-gasen kommer i kontakt med ögat löser den sig i vattnet i ögat och svavelsyra (H_2SO_4) bildas, se Figur 2 nedan. Svavelsyran är det som svider i ögat och en nervrespons triggas så att ögonen tåras och vi börjar gråta. Svidandet fortsätter till dess att all svavelsyra sköljts bort med tårarna [2].



Figur 2. Strukturformel för svavelsyra som bildas då syn-propantial-S-oxid löser sig i tårvätskan. Från [6].

Referenser:

[2] A. Lorén. "Varför svider det i ögonen när man skalar lök?" Skolkemi Umeå. http://chem-www4.ad.umu.se:8081/Skolkemi/Experiment/experiment.jsp?id=124 (Hämtad: 16 mars 2021)

[3] National Center for Biotechnology Information, "3D conformer of 1-propenyl-sulfenic acid". [Elektronisk bild]. Tillgänglig: https://pubchem.ncbi.nlm.nih.gov/compound/1-Propene-1-sulfenic-acid#section=3D-Conformer. Pubchem identifier: CID 25201770. (Hämtad: 16 mars 2021)

[4] National Center for Biotechnology Information, "3D conformer of Propanethial S-oxide". [Elektronisk bild]. Tillgänglig: https://pubchem.ncbi.nlm.nih.gov/compound/441491#section=3D-Conformer. Pubchem identifier: CID 441491. (Hämtad: 16 mars 2021)

[5] K. Arney. "Propanethial-S-oxide" Royal Society of Chemistry. https://edu.rsc.org/magnificent-molecules/propanethial-s-oxide/3010038.article (Hämtad: 16 mars 2021)

Magsyra och buffert i magen

En av kroppens strategier för att bryta ned maten vi äter är magsyran i magsäcken. Magsyran består av framför allt saltsyra, men den innehåller även vatten, olika enzymer och elektrolyter som till exempel natrium och kalium [7]. Saltsyran (HCl) gör så att pH-värdet i magsyran ligger på ca pH 1-3 [8]. Det låga pH-värdet har två huvudsakliga funktioner. Den första är att bryta sönder maten vi får i oss, framförallt är en sur miljö effektiv för att bryta ned proteiner. Den andra är att vara en del av kroppens immunförsvar. Många bakterier som orsakar sjukdomar trivs inte i en sur miljö och dör därför då de kommer ned i magsyran i magsäcken [7].

För att kroppens egna celler och proteiner inte ska frätas sönder av magsyran (eller brytas ned av de enzymer som finns i magsyran) är magsäckens inre vägg täckt av en slemhinna som skyddar mot syran [8]. Slemhinnan består av lipoproteiner och körtlar som utsöndrar bikarbonat (HCO_3^-). Bikarbonaten fungerar som en buffert och höjer därmed pH-värdet i slemhinnan till pH 7 [7].

Läs mer på:

Britannica: Human Digestive system – gastric mucosa

Kemikalendern, oktober – Hälsa: Den sura magen

Buffertsystem i havet (Version 1)

Havet har i nuläget ett pH-värde på ca 8,1 [9]. Havslevande organismer trivs bra vid detta pH-värde men påverkas negativt om det skulle rubbas. I haven finns dock ett buffertsystem som gör att eventuella förändringar i pH-värdet blir trögare och pH-värdet hålls mer stabilt. Havets buffertsystem består av karbonater som antingen kan ta upp vätejoner, för att motverka en försurning eller släppa ifrån sig vätejoner, för att motverka att pH höjs [9].

Havets buffertsystem gör så att stora mängder koldioxid kan tas upp och man kallar haven därför för ”kolsänkor”. I och med människans ökade utsläpp av koldioxid har dock buffertsystemet börjat nå en topp och pH-värdet i haven har därför börjat sjunka. Detta medför stora negativa konsekvenser för många marina organismer. Ett exempel är organismer som koraller och sjöstjärnor som i en surare miljö inte kan bygga upp sina skal [10].

Läs mer på:

The Nature Education Project – Ocean acidification

Kemikalendern, mars – Klimat och energi: Påverkar din utandningsluft miljön?

Buffertsystem i havet (Version 2)

Havet har i nuläget ett pH-värde på ca 8,1 [9]. Havslevande organismer trivs bra vid detta pH-värde men påverkas negativt om det skulle rubbas. I haven finns dock ett buffertsystem som gör att eventuella förändringar i pH-värdet blir trögare och pH-värdet hålls mer stabilt. Havets buffertsystem består av karbonater, närmare bestämt vätekarbonatjoner (HCO_3^-) och karbonatjoner (CO_3^{2-}). Karbonater är salter till syran kolsyra (H_2CO_3). Kolsyra bildas då koldioxid (CO_2) löser sig i vattnet enligt reaktion R1 och R2 nedan [9].

$$CO_2(g) \leftrightarrows CO_2(aq) \quad \text{R1}$$

$$CO_2(aq) + H_2O(l) \leftrightarrows H_2CO_3(aq) \quad \text{R2}$$

Kolsyran reagerar sedan vidare för att bilda karbonaterna enligt reaktion R3 och R4 nedan.

$$H_2CO_3 + H_2O \rightleftarrows HCO_3^-(aq) + H_3O^+ \quad \text{R3}$$

$$HCO_3^- + H_2O \rightleftarrows CO_3^{2-}(aq) + H_3O^+ \quad \text{R4}$$

Det är dessa jämviktreaktioner som ger den buffrande förmågan [9].

Kombinationen av koldioxid, vätekarbonatjoner och karbonatjoner i haven kallar man för *dissolved inorganic carbon* (DIC), alltså löst oorganiskt kol [9]. Till följd av jämviktsreaktionerna ovan beror fördelningen mellan dessa olika föreningar på vilket pH-värde vattnet har. Vid havets nuvarande pH-värde på ca 8,1 förekommer ca 90% av DIC som vätekarbonatjoner och knappa 10% som och karbonatjoner. Ju lägre pH-värde desto mer av DIC kommer att förekomma som vätekarbonatjoner och desto mindre som karbonatjoner eftersom en ökad mängd oxoniumjoner kommer att driva reaktion R4 åt vänster. En ökad mängd koldioxid orsakar just en sänkning i pH-värde då Reaktion R1-R3 drivs åt höger, vilket ökar mängden oxoniumjoner [9].

Den här förmågan att ta hand om koldioxid och lagra kol som DIC är varför man kallar haven för kolsänkor och det är en stor anledning till att den globala uppvärmningen inte har gått snabbare är den gjort [9]. Konsekvensen av människans ökade koldioxidutsläpp är dock att havets buffrande förmåga håller på att nå sin gräns, karbonaterna klarar helt enkelt inte av att ta hand om överskottet av oxoniumjoner längre, och pH-värdet sjunker därför i våra hav [10]. Det är detta som kallas för havsförsurning och det får stora negativa konsekvenser för marina organismer. Till exempel så använder många djur karbonatjoner i kalciumkarbonat ($CaCO_3$) som byggstenar för att bygga sina skal. Då halten karbonatjoner minskar vid ett sänkt pH får dessa djur svårt att bygga upp sina skal [9].

Referenser:

[9] S. Baker & A. Baker. “Ocean Acidification” Nature Education. https://www.nature.com/scitable/knowledge/library/ocean-acidification-25822734/ (Hämtad: 16 mars 2021)

[10] “Kemikalendern, Mars, Klimat, Påverkar din utandningsluft miljön?”, Chalmers Tekniska Högskola, mars 2011, https://www.chalmers.se/sv/samverkan/skolsamverkan/Grundskolan/kemiaret/Documents/Kemikalendern_Mars_Klimat_och_Energi_Undervisningsmaterial.pdf (Hämtad: 16 mars 2021)

Vardagsprodukter

Några läkemedel mot sura uppstötningar

Halsbränna är ett vanligt problem som uppkommer då magsaften stöts upp i matstrupen. Magsaften är mycket sur, då den innehåller en hög koncentration av saltsyra (HCl), och har ett pH-värde mellan 1 och 3. Detta är för att den ska fungera som ett skydd mot bakterier som kan göra människan sjuk. För att förhindra eller lindra sura uppstötningar finns ett antal olika mediciner [11].

Samarin är ett pulver som löses i vatten och dricks. Det innehåller basen natriumvätekarbonat ($NaHCO_3$) som kan neutralisera saltsyran i magsaften.
Novalucol är ett annat läkemedel som fungerar likadant men innehåller baserna kalciumkarbonat och magnesiumhydroxid istället för natriumvätekarbonat. Samarin och Novalucol är båda exempel på antacida läkemedel [11].

En annan typ av läkemedel för halsbränna, som t.ex. Galviscon och Galieve, innehåller framförallt polysackariden alginsyra. Alginsyran bildar i magsäcken en gel som fungerar som ett lock som stoppar magsaften från att tränga upp i matstrupen. På polysackariden sitter det karboxylatjoner bundna till natrium, alltså $R\text{-}COO^-\ Na^+$. När dessa når magsaften löses de upp och karboxylatjonen, som är en bas, kan istället ta upp vätejoner och neutralisera syran [12].

Ytterligare ett sätt att hindra sura uppstötningar är att minska mängden syra i magen. Det kan göras med så kallade histamin-2-blockerare. Produktionen av magsyra styrs av ämnet histamin. Genom att blockera histaminreceptorerna på magens slemhinnor kan man förhindra produktion av magsyra. Ett annat sätt är genom att blockera de protonpumpar som är nödvändiga för att cellerna magens slemhinnor ska kunna producera saltsyra. Sådana läkemedel kallas protonpupmshämmare [11].

Referenser:

[11] “Läkemedel vid halsbränna - magsaftsreflux.” 1177 Vårdguiden. https://www.1177.se/behandling--hjalpmedel/behandling-med-lakemedel/lakemedel-utifran-diagnos/lakemedel-vid-halsbranna/#section-102970

[12] “Chemistry in your cupboard – Galviscon.” Royal Society of Chemistry. https://edu.rsc.org/resources/chemistry-in-your-cupboard-gaviscon/11.article (Hämtad: 16 mars 2021)

Alkaliska och icke-alkaliska batterier

Kanske har du hört talas om alkaliska och icke-alkaliska batterier. Men vad är egentligen skillnaden? Ett batteri har framförallt tre delar; en anod, en katod och en elektrolyt. Anoden är den positiva sidan av batteriet och katoden är den negativa sidan. Däremellan finns elektrolyten som är ett joniskt ämne som ser till att elektroner kan röra sig mellan batteriets poler. I ett alkaliskt batteri är elektrolyten en bas, vanligtvis kaliumhydroxid (KOH). I ett icke-alkaliskt batteri är elektrolyten istället en syra, ofta en blandning mellan ammoniumklorid (NH_4Cl) och zinkklorid ($ZnCl_2$). De flesta är överens om att alkaliska batterier är något bättre kapacitet än icke-alkaliska. Ibland stöter man på en elektronisk enhet med texten ”endast alkaliska batterier”. Detta är ofta produkter där det behövs en snabb urladdning, till exempel en fotoblixt [13].

Läs mer på:

Sciencing: What Is the Difference Between Alkaline & Non-Alkaline Batteries?

Historiska händelser

Mordet på Rasputin

Gregory Rasputin var en rysk predikant som levde under slutet av 1800-talet och i början på 1900-talet, vars död ledde till störtandet av Romanovdynastin. Rasputin hade nära kopplingar till tsarfamiljen som var övertygade om att han skulle kunna hjälpa deras son som led av blödarsjuka. Det gick dock även rykten om att Rasputin hade en romantisk relation med tsarinnan Alexandra. Eftersom Tsaren inte trodde på dessa rykten fick andra delar av den kejserliga familjen ta saken i egna händer [14].

Prins Felix Jusupov, som var gift med tsarens systerdotter, gjorde tillsammans med några andra mäktiga individer upp en plan för att döda Rasputin. Planen gick ut på att bjuda Rasputin på tårta, förgiftad med cyanid. Rasputin gick rakt i fällan och åt av den förgiftade tårtan, men utan att visa några som helst tecken på förgiftning. Först efter att blivit skjuten flera gånger, slagen och kastad i en frusen sjö dog Rasputin [14].

Men hur kunde Rasputin överleva cyanidtårtan? Lite syra-bas-kemi kan nog ge oss en förklaring på detta. Ämnet som användes för att förgifta tårtan var troligtvis kaliumcyanid, en jonförening där cyanidjonen (CN^-) är den giftiga substansen då den gärna binder med Fe(III) och så förhindrar syretransporten i kroppen. Det är mycket möjligt att kaliumcyaniden som användes hade lagrats i en fuktig miljö. När koldioxid från atmosfären reagerar med fukt, alltså vatten, bildas den svaga syran kolsyra [14].

$$CO_2(g) + H_2O \rightarrow H_2CO_3(aq)$$

Detta är som sagt en svag syra (pK_a 6,3) men den är tillräckligt stark för att reagera med kaliumcyanid och bilda vätecyanid (pK_a 9,3) och kaliumvätekarbonat.

$$H_2CO_3(aq) + KCN(s) \rightarrow KHCO_3(s) + HCN(g)$$

Vätecyanid är en kovalent bunden gas vid rumstemperatur. Troligtvis har därför vätecyanidgasen försvunnit ut i luften och lämnat efter sig den harmlösa kaliumkarbonaten, ett vitt pulver som med blotta ögat är omöjligt att skilja från den giftiga kaliumcyaniden [14].

Läs mer på:

Royal Society of Chemistry – Anecdotes for Chemistry Teachers: The murder of Rasputin

Syra i Regalskeppet Vasa

Regalskeppet Vasa byggdes på 1600-talet och sjönk strax efter att det lämnat Stockholms hamn 1628. År 1961 lyftes skeppet upp igen och ett omfattande konserveringsarbete startade. Ett av problemen som stöttes på var följande. På grund av det mycket förorenade vattnet som fartyget legat i hade stora mängder svavel trängt in i träet. När skeppet lyftes upp började detta svavel reagera med syre och bilda svavelsyra [15, 16].

$$S + O_2 \rightarrow SO_2$$

$$2\,SO_2 + O_2 \rightarrow 2\,SO_3$$

$$3\,SO_3 + H_2O \rightarrow H_2SO_4$$

Svavelsyra är som namnet antyder en syra, vilket drastiskt sänkte pH-värdet i träet ner mot pH 1, något som riskerade förstöra träet. År 2002 uppskattades mängden svavelsyra i Vasas skrov till över 2 ton, och ca 100 kg bildas varje år. Skeppet har behandlats med dukar dränkta i en basisk lösning för att neutralisera det låga pH-värdet, men detta är endast en tillfällig lösning eftersom ny syra bildas hela tiden [15, 16].

Referenser:

[15] S. Andersson, A. Sonesson, O. Svahn, A. Tullberg. *GymnasieKemi 1*, fjärde upplagan, Stockholm: Liber.

[16] “Regalskeppet Vasa” Wikipedia. https://sv.wikipedia.org/wiki/Regalskeppet_Vasa (Hämtad: 16 mars 2021)

Nyheter

Olycka med utsläpp av svavelsyra

Natten till den 4 februari 2005 rämnade cistern 436 vid Kemira Kemi AB i Helsingborgs hamn. Innehållet bestod av 16 300 ton (ca 8 900 m^3) svavelsyra (H_2SO_4, 96 %) som tömdes under 2,5 – 4 min genom en öppning som slets upp i botten på cisternen. Majoriteten av svavelsyran rann över kajkanten och under några inledande minuter reagerade svavelsyran häftigt med kloridjonerna i saltvattnet så att klorväte (HCl) bildades. Klorvätet förflyttades som ett moln, i form av både gas och aerosol, med den sydostliga vinden längs kusten och till största del över havet. Inom industriområdet fanns det stor risk för allvarliga frätskador på människor enligt de beräkningar som utförts av Totalförsvarets Forskningsinstitut, FOI. Cirka en timme efter händelsen närmade sig koncentrationerna i molnet nivåer som kan anses ofarliga. Molnet hade då förflyttat sig ca 10 km. Olyckan orsakade inga allvarliga fysiska personskador [17].

Referenser:

[17] “Olycka med utsläpp av svavelsyra vid Kemira Kemi AB i Helsingborg, M län, den 4 februari 2005”, Haverikommissionen, Rapport RO 2008:02, https://www.havkom.se/assets/reports/Swedish/ro2008_02.pdf (Hämtad: 21 mars 2021)

Redox

I det centrala innehållet i ämnesplanen för kemi i gymnasieskolan står det att undervisningen ska behandla reaktioner och förändringar som

” *Redoxreaktioner, inklusive elektrokemi.*” [1].

Nedan följer exempel på vardagsfenomen, vardagsprodukter, historiska händelser och nyheter som behandlar ovan del av det centrala innehållet.

Vardagsfenomen

Korrosion av koppar (Version 1)

Korrosion är ett fenomen om innebär att ett material ”förstörs” på grund av den omgivande miljön, ofta genom en redox-reaktion [18]. När koppar korroderar sker det i tre steg, vilket gör att det bildas tre skikt på kopparn. Närmast kopparn bildas ett lager av koppar(I)oxid, Cu_2O, när koppar oxideras av syre. I nästa steg reagerar koppar(I)oxiden vidare med syre och bildar koppar(II)oxid, CuO. Det yttersta skiktet, som är det gröna man ska se på statyer eller koppartak, är basisk kopparkarbonat, $Cu_2CO_3(OH)_2$ [19].

Läs mer på:

Skolkemi, Umeå – Experiment: Diffusion av kopparjoner

Korrosion av koppar (Version 2)

Korrosion är ett fenomen om innebär att ett material ”förstörs” på grund av den omgivande miljön, ofta genom en redox-reaktion [18]. Koppar är en ganska ädel metall och är därför i viss mån motståndskraftig mot korrosion, men i närvaro av vatten kan viss korrosion ändå ske. Korrosion av koppar sker i flera steg, viket bildar olika lager på den korroderade kopparn [19].

Närmast den rena kopparn bildas koppar(I)oxid, Cu_2O genom reaktion mellan koppar och syre.

$$4\ Cu(s) + \ O_2 \rightarrow 2\ Cu_2O(s)$$

Reaktionen kan delas upp i en oxidationsreaktion och en reduktionsreaktion.

$$Oxidation\colon 4\ Cu(s) \rightarrow \ 4\ Cu^+ + \ 4\ e^-$$

$$Reduktion\colon O_2 + 4\ e^- \rightarrow 2\ O^{2-}$$

I nästa steg reagerar koppar(I)oxiden vidare med syre och bildar koppar(II)oxid, CuO. Även denna kan som ovan delas upp i en oxidations- och en reduktionsreaktion. När koppar(II)oxiden reagerar med luftens koldioxid och vatten uppkommer basisk kopparkarbonat, $Cu_2CO_3(OH)_2$, som är det kemiska namnet för den blandning av kopparhydroxid och kopparkarbonat som i vanligt tal burkar kallas ärg. Ärg är det gröna skiktet som man kan se på kopparstatyer och –tak [19].

Referenser:

[18] A. Henriksson. *Syntes kemi 1,* andra upplagan, Malmö: Gleerups, 2011, s. 237.

[19] A. Brager & S. Åberg. “Diffusion av kopparjoner.” Skolkemi Umeå. http://chem-www4.ad.umu.se:8081/Skolkemi/Experiment/experiment.jsp?id=18 (Hämtad: 16 mars 2021)

Vardagsprodukter

Jeans färgas med indigoblått (Version 1)

Indigo är inte bara en färg, det är också den molekyl som ger blåa jeans sin färg. Indigo-molekylen är inte vattenlöslig. För att färga tyger som till exempel jeans måste man därför först reducera molekylen, vilket gör den löslig, så att färgämnet kan fastna på tyget. Sedan oxideras molekylerna tillbaka till den olösliga indigon av luften så att tyget blir blått och färgen inte kan tvättas bort [20].

Att färga med indigo är dock en väldigt förorenande process, framför allt steget när man reducerar indigo. Eftersom textilindustrin är så stor har detta en stor påverkan på miljön. Det finns därför forskare som jobbar med att hitta alternativa processer för att tillverka indigo, till exempel med hjälp av bakterier som kan tillverka den reducerade formen av indigo direkt så att man slipper använda så många förorenande kemikalier [21].

Läs mer på:

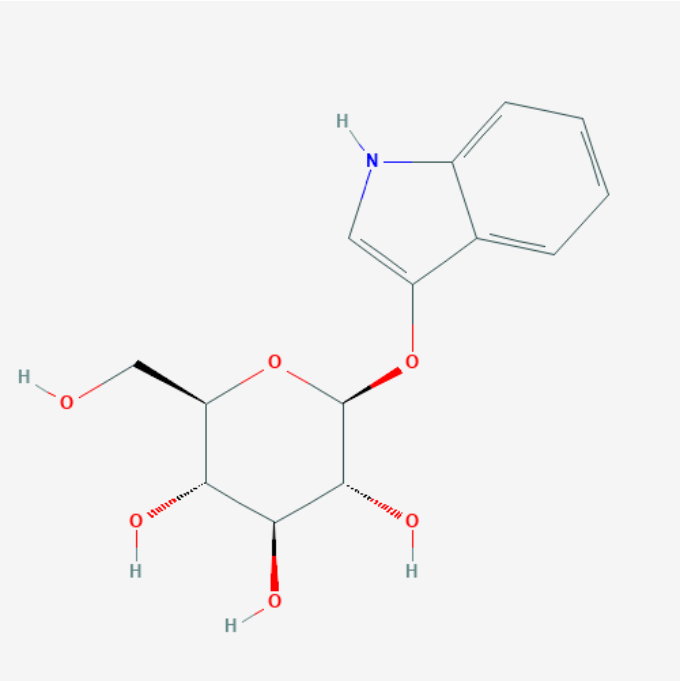
Kemikalendern, januari – Konst och kultur: Indigo

Nature: Chemists go green to make better blue jeans

Jeans färgas med indigoblått (Version 2)

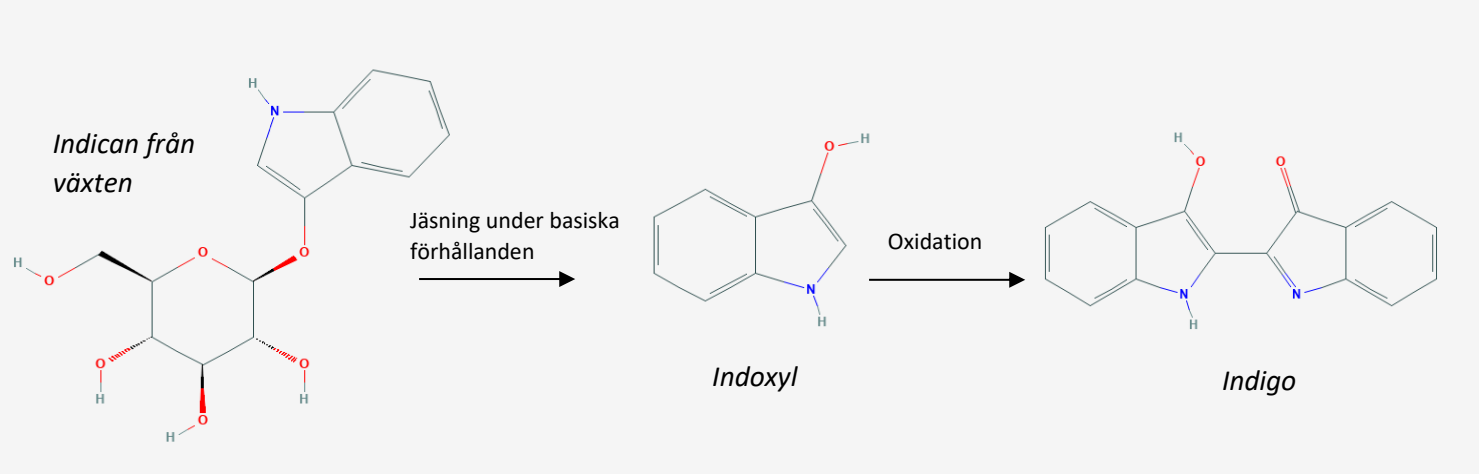
Indigo är inte bara en färg, det är också den molekyl som ger blåa jeans sin färg. Att färga tyger med indigo är något man har gjort i tusentals år. Det tidigaste fyndet har gjorts i Peru och är daterat till att vara ca 6000 år gammalt [22]. Idag framställs indigo syntetiskt men fram till 1800-talet utvann man indigomolekylen ifrån växter, till exempel *Indigofera tinctoria* från Indien [20].

Det är dock inte indigomolekyler som finns i dessa växter, utan ett färglöst ämne som heter indican, se Figur 3.



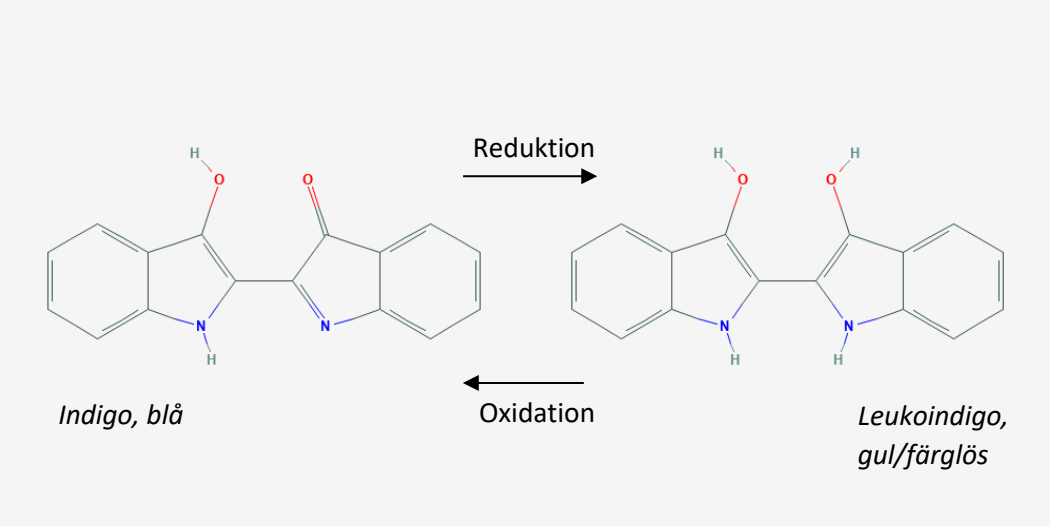
Figur 3. Strukturformel för indican, det ämne som finns i växterna som är en prekursor till indigoblå. Från [23].

För att få indigo måste först indican jäsas under basiska förhållanden, för att bli av med glukosenheten. Då får man den ofärgade molekylen indoxyl som sedan oxideras av syret i luften och bildar den blåa indigomolekylen, se Figur 4.



Figur 4. Reaktionen där indican jäses under basiska förhållanden för att bilda indoxyl, som sedan oxideras till indigo. Strukturformler hämtade från [23], [24], och [25].

Indigo, både syntetiskt framtagen och framtagen ifrån växter som beskrivet ovan, bildar små kristaller som är olösliga, vilket gör att de inte till exempel kan tvättas bort ifrån tyget när det blivit färgat [20]. Det innebär dock också att kristallerna inte kan fästa på tygets fibrer. För att kunna färga tyget med indigo måste man därför först reducera den till något som kallas leukoindigo (eller vit indigo) i ett bad med natriumhydroxid och något reducerande ämne [20]. Leukoindigo är en vattenlöslig, ofärgad molekyl som kan adsorberas till tygfibrerna i ett vattenbad. Tyget är vid detta tillfälle gröngult men när man tar upp det ur färgbadet och tyget kommer i kontakt med luften så oxiderar luftens syre tillbaka leukoindigo till indigo och tyget får sin blå färg [20]. Det sker alltså först en reduktion för att göra färgämnet vattenlösligt så att det kan fastna på tygets fibrer och sedan en oxidation för att göra så att färgämnet får sin blå färg samt blir vattenfast, se Figur 5.



Figur 5. Redoxreaktion där indigo först reduceras till leukoindigo, som sedan oxideras tillbaka till indigo. Strukturformler hämtade från [25] och [26]

Att framställa indigo från växter var mycket resurskrävande och arbetstungt, vilket är varför i princip all indigo som används idag framställs syntetiskt. Dock är själva syntesen och reduktionen från indigo till leukoindigo fortfarande väldigt resurskrävande processer som kräver starka, förorenande

kemikalier [21]. Utsläppen ifrån textilindustrin, däribland färgning av till exempel jeans, är bland de största i världen och därför finns det mycket att vinna på att hitta en mer miljövänlig metod för färgning med indigo [21].

Några forskare har närmat sig genom att använda genmodifierade *E. coli* bakterier som kan producera och utsöndra indican, alltså samma molekyl som fanns i växterna man använde tidigare [22]. Sedan löses indican i vatten tillsammans med ett enzym som kan klippa bort glukosenheten så att man får indoxyl. Indoxyl oxiderar spontant direkt till leukoindigo som sedan används för att färga tyger på samma sätt som ovan [22]. Detta verkar vara en mycket lovande metod för att minska utsläppen ifrån textilindustrin då man slipper både syntesprocessen av indigo och steget då man måste reducera indigo till leukoindigo. Dock är det en bit kvar innan denna process kan skalas upp till den storlek som behövs för att kunna bemöta den stora efterfrågan på indigofärgade tyger som finns idag [22].

Referenser:

[20] “Kemikalendern, januari, Konst och Kultur, Indigo”, Chalmers Tekniska Högskola, https://www.chalmers.se/sv/samverkan/skolsamverkan/Grundskolan/kemiaret/Documents/Kemikalendern_Januari_Konst_och_kultur_Undervisningsmaterial.pdf (Hämtad: 16 mars 2021)

[21] Nature Editorial. “Chemists go green to make better blue jeans” Nature. https://www.nature.com/articles/d41586-018-00103-8 (Hämtad: 16 mars 2021)

[22] J. Splitstoser, T. D. Dillehay, J. Wouters och A. Claro. “Early pre-Hispanic use of indigo blue in Peru” Science Advances, vol 2, nr. 9, Sept. 2016, [Online], Tillgänglig: https://www.researchgate.net/publication/308128743_Early_pre-Hispanic_use_of_indigo_blue_in_Peru

[23] National Center for Biotechnology Information, “2D structure of indican”. [Elektronisk bild]. Tillgänglig: https://pubchem.ncbi.nlm.nih.gov/compound/441564#section=2D-Structure. Pubchem identifier: CID 441564. (Hämtad: 16 mars 2021)

[24] National Center for Biotechnology Information, “2D structure of indoxyl”. [Elektronisk bild]. Tillgänglig: https://pubchem.ncbi.nlm.nih.gov/compound/50591#section=2D-Structure, Pubchem identifier: CID 50591. (Hämtad: 16 mars 2021)

[25] National Center for Biotechnology Information, “2D structure of indigo”. [Elektronisk bild]. Tillgänglig: https://pubchem.ncbi.nlm.nih.gov/compound/10215#section=Structures, Pubchem identifier: CID 10215. (Hämtad: 16 mars 2021)

[26] National Center for Biotechnology Information, “2D structure of leucoindigo”. [Elektronisk bild]- Tillgänglig: https://pubchem.ncbi.nlm.nih.gov/compound/23035#section=2D-Structure, Pubchem identifier: CID 23035. (Hämtad: 16 mars 2021)

Permanenta håret (Version 1)

Håret består bland annat av proteinet keratin. Keratin binds samman av svavelbryggor, som då ger håret sin form. När man permanentar håret vill man få det till att ändra form, ofta från rakt till lockigt. Det gör man genom att först reducera svavelbryggorna så att bindningarna mellan keratinmolekylerna bryts. Sedan lägger man håret i den form man vill ha det, till exempel med hjälp av hårrullar. När håret ligger som man vill ha det återskapar man bindningarna i svavelbryggorna mellan keratinmolekylerna genom att oxidera dem och formen blir då permanent [27].

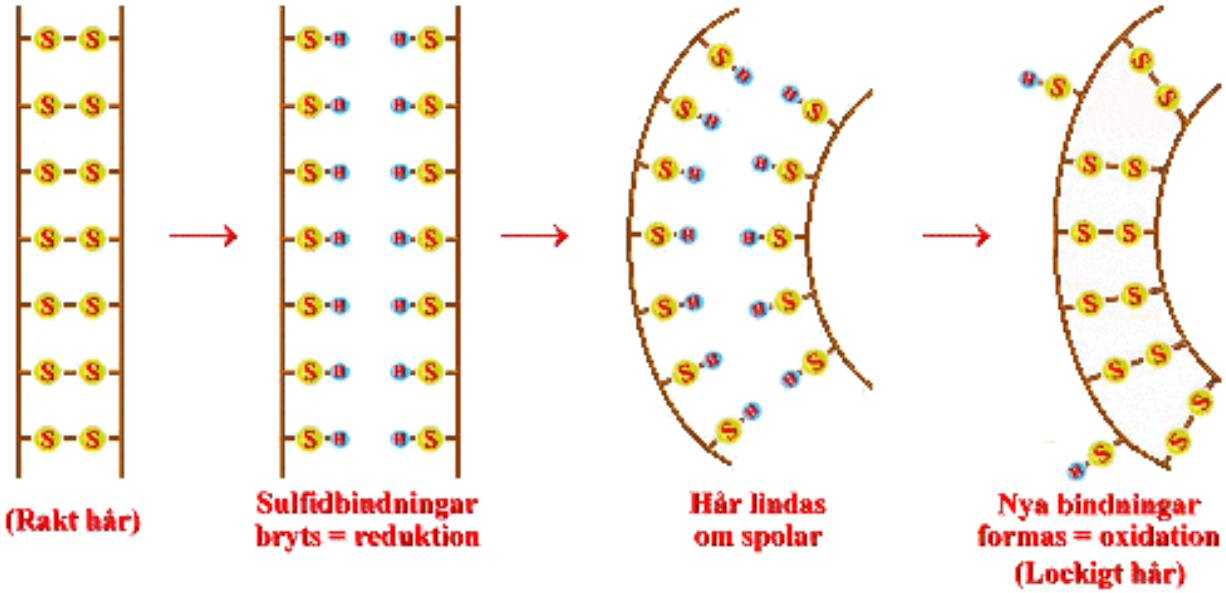
Läs mer på:

Skolkemi, Umeå – Experiment: Permanenta håret

Permanenta håret (Version 2)

Håret består bland annat av proteinet keratin. I keratin finns aminosyran cystein. Keratinmolekylerna i håret binder till varandra med svavel-svavelbryggor mellan sulfider i cysteinet. Dessa bryggor kan brytas genom att ett reduktionsmedel tillsätts som bryter bindningen mellan svavelatomerna och reducerar dem till sulfhydrylgrupper (R-SH). Exempel på reduktionsmedel som används är ammoniumtioglykolat [27].

När svavelatomerna reducerats lägger man håret i den form man vill har det, till exempel runt hårrullar, och sedan tillsätts ett oxidationsmedel. Då oxideras sulfhydrylgrupperna så att svavel-svavelbryggorna kan återbildas och håret har då fått en ny form. Som oxidationsmedel används till exempel väteperoxid eller natriumperborat [27]. Se en schematisk bild av processen i Figur 6.



Figur 6. Schematisk bild över bindningar mellan keratinet i hårstrån under permanentprocessen. Bild återgiven med tillåtelse av Svante Åberg, Skolkemi Umeå. Från [28]

Referenser:

[27] A. Andersson. "Permanenta håret" Skolkemi Umeå. http://chem-www4.ad.umu.se:8081/Skolkemi/Experiment/experiment.jsp?id=134 (Hämtad: 16 mars 2021)

[28] Svante Åberg, "Permanenta håret". [Elektronisk bild]. Tillgänglig: http://chem-www4.ad.umu.se:8081/Skolkemi/Experiment/experiment.jsp?id=134. (Hämtad: 16 mars 2021)

Hydrogen fuel cells – framtidens drivmedel? (Version 1)

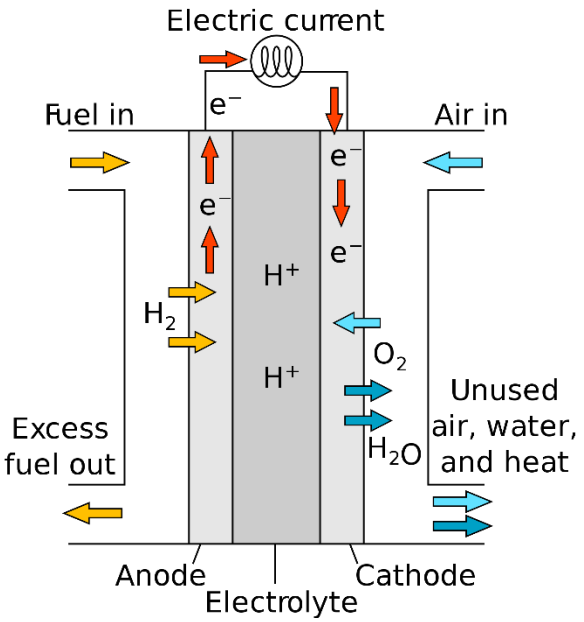
Elbilarna idag använder sig av batterier som man måste ladda upp. Ett möjligt alternativ för att slippa detta är vad man kallar för *hydrogen fuel cells*, en typ av bränslecell. Dessa bränsleceller producerar också el men istället för att elen är lagrad som i ett batteri så skapas elen kontinuerligt i en kemisk redox-reaktion [29]. Så länge man har bränsle (vätgas) och tillgång till syre (via luften) så kan el produceras. Fördelen är då att man inte behöver ladda upp batterier utan man kan fylla på bränsletanken med vätgas på samma sätt som man gör med bensin eller diesel [29].

Läs mer på:

An Introduction to Fuel Cells and Hydrogen Technology

Hydrogen fuel cells – framtidens drivmedel? (Version 2)

Elbilarna idag använder sig av batterier som man måste ladda upp. Ett möjligt alternativ för att slippa detta är vad man kallar för *hydrogen fuel cells*, en typ av bränslecell. Gemensamt för alla typer av bränsleceller är att de består av två elektroder, anoden där oxidation sker och katoden där reduktion sker, och någon form av elektrolyt. Det finns olika typer av bränsleceller som skiljer sig åt beroende på vilken typ av elektrolyt som används [29]. I Figur 7 finns en schematisk bild över en generisk bränslecell.



Figur 7. Schematisk bild över en bränslecell. Från [31] CC0 1.0.

Den typen av bränslecell som ser lovande ut för användning i bilar kallas för *Proton Exchange Membrane Fuel Cells* eller *Polymer Electrolyte Fuel Cells* (PEMFC). I en PEMFC består elektrolyten av en syra, som inte dissocierar i det mediet (en så kallad *solid acid*) och är mättad med vatten för att möjliggöra jontransport [30]. Reaktionerna i en PEMFC-cell ser ut som följer.

Vid anoden används en palladium-katalysator för att bryta bindningen mellan väteatomerna i vätgasen från bränslet. Vätena kan då oxideras till vätejoner och släppa ifrån sig sina elektroner enligt Reaktion 1 [30].

$$H_2(g) \xrightarrow{Pd} 2H^+ + 2e^- \qquad \text{R1}$$

Vätejonerna reagerar sedan med vattnet i elektrolyten och transporteras då till katoden i form av oxoniumjoner (H_3O^+). Vid katoden används också en palladium-katalysator för att bryta bindningarna i syrgasen ifrån luften. Syret reagerar sedan med vätejonerna, som gått genom elektrolyten, och elektronerna, som gått igenom en yttre krets, för att bilda vatten [30].

$$1/2\, O_2 + 2H^+ + 2e^- \rightarrow H_2O\ (l) \qquad \text{R2}$$

Reaktion 2 är en exoterm reaktion så restprodukterna i en bränslecell är vatten och värme.

Fördelar med bränsleceller gentemot förbränningsmotorer är till exempel högre verkningsgrad och att utsläppen inte är förorenande. Den nackdelen man hittills sett är framför allt kostnaderna för

palladium-katalysatorn. Det kommer också krävas en hel del tid och resurser innan det finns en fungerande infrastruktur för bilar som är drivna med bränsleceller, till exempel tillräckligt med tankstationer [29, 30].

Referenser:

[29] “Fuel cells”, Hydrogen Europe, https://www.hydrogeneurope.eu/fuel-cells (Hämtad: 16 mars 2021)

[30] C. Brian, “An introduction to fuel cells and hydrogen technology”, Heliocentris, Kanada. Tillgänglig: https://www.ogniwa-paliwowe.info/download/introduction_to_fuel_cells_and_hydrogen_technology.pdf

[31] Mattuci, ”Proton Exchange Fuel Cell Diagram”. [Elektronisk bild]. Tillgänglig: https://commons.wikimedia.org/wiki/File:Proton_Exchange_Fuel_Cell_Diagram.svg. (Hämtad: 16 mars 2021)

E-nummer och antioxidantmedel

På livsmedelsförpackningar används så kallade E-nummer för att beteckna livsmedelstillsatser. Beteckningarna E300 – E399 betecknar olika antioxidantmedel. Det är ämnen som förhindrar att livsmedlets oxideras genom reaktion med syret i luften. Ett sådant ämne är askorbinsyra (vitamin C, E300). Den hittas bland annat i potatisprodukter där den förhindrar att potatisen reagerar med luften och blir brunfärgad [32].

Referenser:

[32] A. Henriksson. *Syntes kemi 1,* andra upplagan, Malmö: Gleerups, 2011, s. 226.

Historiska händelser

Korrosion till havs

På 1700-talet var det vanligt att ett kopparhölje sattes på skrovet av träskepp för att skydda från havstulpaner och andra organismer som kunde skada skeppet under vattenlinjen. Det fanns dock ett problem med detta. Järnbultar användes för att hålla ihop olika delar av träskrovet och när dessa kom i kontakt med kopparhöljet i saltvatten uppstod ideala förhållanden för bimetallkorrosion. Järn, den mer reaktiva av metallerna, agerar då anod och oxideras till vattenlösliga joner samtidigt som koppar blir katod och reduceras genom att ta upp elektronerna [33].

$$Anod: Fe(s) \rightarrow Fe^{2+}(aq) + 2\,e^{-}$$

$$Katod: Cu^{2+}(aq) + 2\,e^{-} \rightarrow Cu(s)$$

Denna förlust av järn kunde leda till att bultarna gick sönder, vilket kunde få förödande konsekvenser. Det finns (obekräftade) uppgifter om att kopparhöljet plötsligt lossnat från båtar vilket fått dem att kapsejsa [33].

Ett annat exempel på detta kan finnas på stora skepp idag som har skrov av stål (alltså huvudsakligen järn). För att skydda skrovet mot korrosion använder man sig av offeranoder av zink, eller ibland magnesium. Den mer reaktiva zinken korroderar fortare och skyddar på så sätt järnet.

$$Anod: Zn(s) \rightarrow Zn^{2+}(aq) + 2\,e^{-}$$

$$Katod: Fe^{2+}(aq) + 2\,e^{-} \rightarrow Fe(s)$$

Zinken korroderar alltså bort och behöver bytas regelbundet [33].

Referenser:

[33] “Copper Bottomed” Royal Society of Chemistry. https://edu.rsc.org/download?ac=11183 (Hämtad: 16 mars 2021)

Nyheter

Elektrolys för fossilfri stålproduktion

”LKAB:s omställning till fossilfri järnproduktion kommer att kräva sällan skådade vätgasvolymer. Det sätter plötsligt elektrolysörerna i rampljuset. Men vilken teknik har störst potential? Och hur ska den skalas upp?” skriver tidningen NyTeknik 18 februari 2021, och presenterar fyra tekniker för att producera vätgas genom elektrolys [34]. Se infografik här: https://www.nyteknik.se/premium/elektrolysorer-blir-nyckeln-i-lkab-s-omstallning-7009896#7010164

Referenser:

[34] J. Kristensson. “Elektrolysörer blir nyckeln i LKAB:s omställning” NyTeknik. https://www.nyteknik.se/premium/elektrolysorer-blir-nyckeln-i-lkab-s-omstallning-7009896#7010164 (Hämtad: 16 mars 2021)

Världskostnaden för korrosion

År 2013 var den totala samhällskostnaden på grund av korrosion i världen 2,5 biljoner dollar, alltså 2 500 miljarder dollar. Genom att använda sig av tillgängliga tekniker för att förhindra korrosion skulle man kunna spara mellan 15 och 35% av kostnaden, alltså mellan 375 och 875 miljarder dollar, varje år [35].

Referenser:

[35] ”Economic impact: Assessment of the global cost of corrosion” NACE International Impact. http://impact.nace.org/economic-impact.aspx (Hämtad: 16 mars 2021)

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[1] Skolverket. “Ämnesplan kemi.” skolverket.se. https://www.skolverket.se/undervisning/gymnasieskolan/laroplan-program-och-amnen-i-gymnasieskolan/gymnasieprogrammen/amne?url=1530314731%2Fsyllabuscw%2Fjsp%2Fsubject.htm%3FsubjectCode%3DKEM%26tos%3Dgy%26sv.url=12.5dfee44715d3515cdfa9213 (Hämtad: 16 mars 2021)

[2] A. Lorén. “Varför svider det i ögonen när man skalar lök?” Skolkemi Umeå. http://chem-www4.ad.umu.se:8081/Skolkemi/Experiment/experiment.jsp?id=124 (Hämtad: 16 mars 2021)

[3] National Center for Biotechnology Information, ”3D conformer of 1-propenyl-sulfenic acid”. [Elektronisk bild]. Tillgänglig: https://pubchem.ncbi.nlm.nih.gov/compound/1-Propene-1-sulfenic-acid#section=3D-Conformer. Pubchem identifier: CID 25201770. (Hämtad: 16 mars 2021)

[4] National Center for Biotechnology Information, ”3D conformer of Propanethial S-oxide”. [Elektronisk bild]. Tillgänglig: https://pubchem.ncbi.nlm.nih.gov/compound/441491#section=3D-Conformer. Pubchem identifier: CID 441491. (Hämtad: 16 mars 2021)

[5] K. Arney. “Propanethial-S-oxide" Royal Society of Chemistry. https://edu.rsc.org/magnificent-molecules/propanethial-s-oxide/3010038.article (Hämtad: 16 mars 2021)

[6] National Center for Biotechnology Information, ”3D conformer of Sulfuric acid”. [Elektronisk bild]. Tillgänglig: https://pubchem.ncbi.nlm.nih.gov/compound/1118#section=3D-Conformer. Pubchem identifier: CID 1118. (Hämtad: 16 mars 2021)

[7] Britannica. “Human digestive system” https://www.britannica.com/science/human-digestive-system/Gastric-mucosa (Hämtad: 16 mars 2021)

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