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What are the knowledge gaps of students in chemistry and how are they affected by teacher's prioritization of topics?

A comparison between Swedish upper secondary school and university

Master thesis in Leadership and Learning

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CHALMERS TEKNISKA HÖGSKOLA
Göteborg, Sverige 2021
www.chalmers.se

Abstract

The purpose of education in the Swedish upper secondary school is described in The Education Act and as such defines the foundation for the recruitment to higher education, which is the topic of this thesis. The curriculum in Swedish upper secondary school is regulated at a national level, meaning there is a standard for which topics are to be covered in each course. The "central content", which is described by the Swedish National Agency for Education, lists what topics a course is required to cover. It is therefore of interest to investigate how teachers prioritize and interpret different topics in chemistry.

Our goal is to answer the following questions:

- Which are the knowledge gaps in chemistry between upper secondary school and universities, from the perspective of teachers at both levels?
- How does prioritization and interpretation of topics taught within upper secondary school chemistry affect the student knowledge gaps that exist between upper secondary school and university, from the perspective of teachers at both levels?

This project uses a mixed method, meaning both interviews and surveys were conducted. The results are grouped into four parts, Prioritization of topics in chemistry at both levels, What students find difficult in chemistry, according to teachers, University teachers' opinions on undergraduates' lack of knowledge and The opinion of teachers on the curriculum at upper secondary school. Findings in each part of the result is discussed and analysed separately.

Several factors which influence the knowledge gaps of students and why teachers prioritize topics as they do were found to be the following.

Knowledge gaps:

- Upper secondary school teachers rarely teach chemical bonding using atomic orbitals
- Differences in education between different upper secondary schools
- How students use and understand mathematics in the context of chemistry.

What influences topic prioritization and its effects on knowledge gaps:

- The different approaches teachers use to create interest amongst students.
- The effects of different chemistry textbooks.
- The adaptation for differences in groups of students by teachers.

Suggested measures to remove these knowledge gaps can be summarized into three points. Teachers should primarily teach chemical bonding using atomic orbitals instead of Bohr's atom model to the extent possible. More distinct goals for *Chemistry 1* and *Chemistry 2* should be specified through a national obligatory test. Increase pedagogical discussion and collaborations between university and upper secondary school.

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Glossary

This project uses the Swedish National Agency for Education's own list of translated concepts to the extent possible. [1]

Grundskola - Compulsory school
Gymnasieskolan - Upper secondary school
Kemi 1 - *Chemistry 1*
Kemi 2 - *Chemistry 2*
Naturkunskap - *Science Studies*
Skolverket - Swedish National Agency for Education
Skollagen - The Education Act
Ämne - Subject

Further there are some words that are not mentioned by the Swedish National Agency for Education, but still relevant for our project.

Arbetsmarknad - Labour market
Arbetsområde - Topic
Betyg - Grade
Centrala innehållet - The central content
Enhetsanalys – Dimensional analysis.
Förkunskaper - Prior knowledge
Grundläggande behörighet - Fundamental requirements
Högskolelagen – The Higher Education Act
Högstadiet – Lower secondary school
Studieförberedande - Study preparation
Universitet/Högskola - University
Yrkesförberedande - Vocational preparation

1. Introduction

1.1 Background

According to the Swedish Public Employment Service's forecast for chemical engineers, the number of graduates will not be enough to satisfy the national demand within five years[2]. Out of all Master of Science in Engineering undergraduates, only 51% graduate within the normal timeframe[3]. The majority of those who have not graduated at the end of their normal timeframe have more than a year's worth of courses they have not passed[3]. There could be several reasons why so few graduate on time. One possible reason could be that how upper secondary schools (for Swedish translations see glossary) and universities prioritize topics in chemistry differently. The purpose of education in the Swedish upper secondary school is described in The Education Act as a foundation for the recruitment to higher education[4]. It is therefore of national interest that upper secondary school teaches the students not only the knowledge necessary, but also prioritize what they teach to achieve this goal. The student's knowledge should be useful and applicable to ease their transition to the next level of chemistry studies.

The curriculum in Swedish upper secondary school is regulated at a national level, meaning there is a standard for which topics are to be covered in each course. This required material is denoted the central content and is described by the Swedish National Agency for Education as a list of topics a course is required to cover. It is however up to the teachers themselves to choose how much of each topic to cover and whether to add extra topics besides what is listed in the central content[5]. The leeway which teachers have could be utilized to adapt the course material to what the universities want students to be prepared for.

1.2 Aim of study and research question

In order to identify knowledge gaps between upper secondary schools and universities, interviews with teachers at both levels was held. As one purpose of upper secondary schools is to prepare the student for university studies, it is therefore of interest to investigate how teachers at the two levels prioritize and interpret different topics. We aim to identify these topics through interviews, including which topics undergraduates often struggle with.

Our goal is to answer the following questions:

- Which are the knowledge gaps in chemistry between upper secondary school and universities, from the perspective of teachers at both levels?
- How does prioritization and interpretation of topics taught within upper secondary school chemistry affect the student knowledge gaps that exist between upper secondary school and university, from the perspective of teachers at both levels?

1.3 Delimitations.

To answer our questions, we will interview chemistry teachers at both upper secondary schools and universities. The upper secondary school teachers who will be interviewed are teaching or have taught both *Chemistry 1* and *Chemistry 2*. The selected universities are Chalmers University of Technology and Gothenburg University, from which we will interview teachers. The upper secondary school teachers work mainly within the Gothenburg area. The reason behind the more geographically restricted approach is mainly due to the lack of resources.

Most universities that teach chemistry require students to have passed specifically the courses *Chemistry 1* and in some specific cases *Chemistry 2*, which are normally taught only at study preparing programmes with a science or technology focus in upper secondary school. Since these courses are required to qualify for many institutes of higher education within chemistry, this study will use these two courses as reference for further comparison between the levels of education. The comparison will use the central content as a reference as to which topics are taught by upper secondary school teachers. The central content of *Chemistry 1* and *Chemistry 2* is listed in Appendix 1. Similarly, surveys and interviews of chemistry teachers from the two universities will use the central content to investigate what they consider important within chemistry when studying at university.

Our choice to only study the experiences of teachers and not students is deliberate. Teachers have often met hundreds of students during their profession. This allows the teachers to share their collective experience about their students' knowledge and possible knowledge gaps, which students alone are not necessarily aware of.

2. Theory

2.1 Previous research

Several previous studies have been made regarding prior knowledge in chemistry of Swedish students and their transition from upper secondary school to university. One master thesis[6] explored perceived prior knowledge in Chemistry of students in comparison to the needs of university studies. They found that students themselves believe they have adequate prior knowledge whereas the university teachers have noticed a decline in prior knowledge, which they counteract by adjusting the introductory courses in Chemistry. The students in the study also expressed a wish to have learnt more thermodynamics in upper secondary school.

Another master thesis[7] explored whether there are any knowledge gaps between upper secondary school and university concerning chemical bonding, including how students experience the transition between the two. It was found that the students experienced difficulties to differentiate between different types of chemical bonds and secondly that all students notice a difference in how the concept of chemical bonding is taught between upper secondary and university education. The students in the study felt that the difference in work procedures and the amount of theory used at university was the largest challenge in this transition.

A study[8] in the United States asked college and university students at introductory level about their high school background, to see if there was any connection between their high school chemistry background and their college grades in chemistry. They found that students whose high school education had heavy emphasis on stoichiometry scored higher at college level chemistry than their peers. Stoichiometry appears to be a highly significant predictor to college chemistry performance. Closely related to stoichiometry, they also found mathematics to be a highly significant predictor to college chemistry performance. They explain that, while advanced mathematics are not part of introductory chemistry courses at college level, students who have studied topics such as calculus at high school have a higher likelihood to have the necessary mathematical proficiency to follow and comprehend the material in chemistry at college level.

A Swedish study[9] compared science teachers' beliefs in teaching to what students want to learn in science. In their study they also investigated factors that affect the teachers' choice of content in their lessons. The science teachers' beliefs of teaching supposedly stem from their earlier experiences, but it is pointed out that even if teachers have certain beliefs of how and what to teach, it is not always implemented. They found that the curriculum and syllabi, teachers' own thoughts, colleagues, students' wishes and burning questions in society were factors that affected the science teachers' choice of content and planning for their science lessons. One conclusion they draw is: "to help teachers improve secondary school science, collaboration is needed".

2.2 Upper secondary school in Sweden

Described by The Education act[4], education held at Swedish upper secondary schools builds upon knowledge students get from the Swedish compulsory school or education equivalent to it. Students are required to have finished compulsory school or equivalent education to begin their studies at upper secondary school. The student must begin before or during the first half-year the student will turn 20 years of age to still be eligible. The purpose of the education at upper secondary school is to set a foundation for the national and regional skills supply to the labour market, as well as a foundation for the recruitment to higher education.

Further defined in The Education act[4], Swedish upper secondary school is divided into national programs that can be categorized into two types: study and vocational preparation programmes. There are five study and 12 vocational preparation programmes in total. Vocational preparation programmes are to set a foundation for professional activities and continued vocational education. Vocational preparation programmes are also supposed to give students an opportunity to reach the fundamental requirements to apply for studies at university level, within the framework of their selected programme. Study preparation programmes are to set a foundation for further studies at university level. This would imply students will get the opportunity to reach, not only the fundamental requirements, but all requirements for further studies at university level, within the framework of their selected programme.

2.2.1 Chemistry in upper secondary school in Sweden

Chemistry at upper secondary school is given in two courses specified by the Swedish National Agency for Education, *Chemistry 1*, and *Chemistry 2*[10]. Just like every other course at upper secondary school, they follow a national standard of topics named the central content, see Appendix 1. The teacher giving the course is obligated to cover all the topics within the central content. However, the teacher is free to choose how much of every topic to cover and whether to add extra topics besides what are listed in the central content[5]. The Education act states that *Chemistry 1* and *Chemistry 2* shall only be taught at certain study preparation programmes, specifically at the Natural Science Programme and Technical Programme. All other programmes are required to contain a course in *Science Studies* instead, which covers the natural sciences as a whole[4]. Students could still have a chance to study chemistry, as every programme allows students to pick a few courses for themselves. However, each programme is only allowed to offer specific courses from a list, which differ from programme to programme. Listed by the Swedish National Agency for Education, programmes such as the vocational preparing Handicraft Programme is eligible to give the course *Chemistry 1*[11] and the vocational preparing Industrial Technology Programme is eligible to give *Chemistry 1* and *Chemistry 2*[12].

2.2.2 Teacher's influence and purpose

The American National Research Council[13], describes how "high school teachers can have a tremendous impact on students' interest and performance in the sciences". They mention that many scientists can think back about some especially inspiring teachers during their own high school years and that high school teachers often report that old students have told them of how their experiences in that teacher's class have helped them succeed in college.

As teachers can have a large impact on students, they also have large influence over what skills our next generation of citizens will develop, as they are one of our society's main distributors of knowledge. What knowledge should be conveyed by teachers is often regulated by state agencies, which also to some degree is the case in Sweden. As mentioned earlier about the central content of courses that is regulated by the Swedish National Agency for Education[5], teachers must cover every topic listed by the central content but can decide by how much and whether or not to add additional topics themselves to their course syllabus. The leeway that exists allows teachers to adapt their courses how they see fit. This raises questions such as: what are teachers expected to prioritize and what arguments exist for prioritizing certain topics above others?

2.2.3 The influence and purpose of teachers

As mentioned previously, the Education act[4] states how upper secondary school is supposed to prepare students to join the Swedish labour market as well as have them qualify for higher education. To relate to the subject of chemistry, the Swedish National Agency for Education[10] defines the subject's purpose in more detail, describing, in addition to providing chemistry knowledge as such, how education should contribute to the students' ability to participate in public debates, discuss ethical questions and standpoints from a scientific point of view. Further, it is described how education should contribute to the students' ability to develop critical thinking and distinguish scientific statements from non-scientific ones. These purposes of chemistry as a subject could be summarized as to reach adequate scientific literacy within the general public.

Chemistry as a subject has two distinct purposes, to build adequate scientific literacy whilst also educating students aspiring to pursue higher education. One study[14] that discusses this duality describes how the two purposes could be in conflict. It is observed that many science curricula have both purposes to fulfil often put an emphasis on the so-called pre-professional training. In England, attempts to resolve this tension have been made nationwide by splitting up their science class (15-16 years old students) in two equally large courses: one *Core Science* course, aimed to develop scientific literacy, and another optional *Additional Science* course. Students who have taken both courses, *Coreplus-Additional*, would have a solid foundation to seek out more advanced science education onwards. It is argued in the article that the expectation of stakeholders, who prioritize the purpose of educating aspiring university students, have been met by offering the course *Additional Science* to those students who want to take it. Similarly, the expectation of stakeholders, who prioritize scientific literacy, have also been met as every student is required to take the *Core Science* course.

2.2.4 The influence of textbooks

In a report written by The Swedish Schools Inspectorate[15], they criticize how teachers use textbooks in Swedish primary schools. Many teachers lack the background to understand the purpose of topics described in the course syllabi. This results in the teachers relying more on their textbooks, as they expect the textbook writers to have interpreted the course syllabi feasibly well. As another study[16] describes it, the textbook functions as the actual syllabus as it often is the basis of knowledge transfer. Teachers in Scandinavia and other countries in the world are prone to follow their textbook rather than plan the course on their own or according to the syllabus, meaning that the textbook has major influence over what and how the subject is taught. The same study[16] also proposes that the main issue with textbooks in science is that they contain too many details and facts, which makes it difficult for students to understand the purpose of science.

2.3 University system

Stated in the Higher Education Act[17], the purpose of universities in Sweden is to have an education based on scientific or artistic grounds and proven experience, as well as conducting research and development. In this project two universities are of interest, Chalmers and Gothenburg University.

Chalmers is a private university owned by the Chalmers University of Technology Foundation. The university is overseen by agreement with the Swedish government[18]. To start studying at the university you must have reached the fundamental requirements and passed the upper secondary courses *Physics 2*, *Chemistry 1*, *Mathematics 4* and *English 7*[19]. Gothenburg University is a university of state meaning it is controlled by the government. To start studying at Gothenburg University you must have reached the fundamental requirements and passed the upper secondary courses *Physics 2*, *Chemistry 2* and *Mathematics 4*[20]. It is noticeable that Chalmers and GU have different requirements to qualify for their chemistry programmes.

2.4 What is Knowledge?

Oxford Learner's Dictionary of Academic English define knowledge[21] as "the understanding of a subject that is gained through study, research or experience". This definition of knowledge still poses the question of what the word understanding is defined as. When investigating every keyword (understanding, realize and aware)[21] that formulate the definition of knowledge in the dictionary, it is clear that they create a closed loop of defining each other.

In more general terms, a definition of knowledge is presented by Gettier[22] as justified, true belief, referencing one of Plato's dialogues Theaetetus. For a person to know a given proposition, the proposition must be true, the person must believe the proposition to be true and have justification for believing that proposition to be true. However, Gettier found this definition inadequate, as a person can have a justified, true belief but not knowledge of a proposition. This is exemplified by Gettier by the possibility of a person holding a justified belief that is based on faulty reasoning yet still holds true, posing the possibility of a person having a justified true belief yet no knowledge.

Since knowledge transfer is key within every educational institute, a relevant distinction should be made between perceived and actual knowledge. A study[23] describes perceived knowledge as the individual's self-assessment of knowledge whereas actual knowledge is what information the individual in fact possesses. Another study[24], which explored these concepts based on information search behaviour, found a weak correlation between perceived and actual knowledge. Further, the same study found that individuals are biased assessors of their own knowledge levels. With these findings in mind, expecting students or undergraduates to assess their actual knowledge correctly would likely give unreliable results.

3. Methodology

3.1 Research design

The purpose of this project is to improve our understanding and to identify knowledge gaps that exist according to teachers, between upper secondary schools and universities. In order to get an improved overview of the situation a qualitative research was conducted. Qualitative research can be defined as “an iterative process in which improved understanding to the scientific community is achieved by making new significant distinctions resulting from getting close to the phenomenon studied”[25]. Since school systems differ between each individual country, similar investigations outside of Sweden are hard to apply to our research in a meaningful way. An approach based on qualitative research overall fits the goals of our project and provides adequate analysis of the situation between teaching at both levels. Further, due to the shortage of research in this field, we judged that a smaller quantitative study would be needed to increase the validity of the project. The decision to use both surveys and interviews was therefore made and is described in detail below.

The project was divided into three phases. First, a preparation phase where the focus was to prepare and create the survey and the interviews. The survey was sent out before the interviews and would later be used as a basis for the interviews. The template of the interview was created based on the answers of surveys to increase the effectiveness and design a basic structure for each interview.

The second phase of the study focused on carrying out individual interviews with teachers from either upper secondary school or university. Before every interview, their answers from the survey were discussed and added to their interview template. Fifteen interviews in total were conducted, eight from upper secondary school and seven from university. These interviews were then transcribed and anonymized.

The third and last phase of the study was analysis of interviews in context of answers from survey. Identification of keywords and unifying themes from the interviews were found. These were then compiled to a result and analysed based on the further literature studies. Finally, the result was used as a basis to compare the perspectives of teacher from upper secondary school and university.

3.1.1 Ethical considerations

The ethical aspects that were taken into consideration in this project was to anonymize all responses from interviewees and survey respondents. Therefore, the decision was made to anonymize all participants by transcribing their interviews, excluding any names mentioned. A codenaming system was constructed so only researchers in this project could back-track to which transcription belongs to which interviewee.

3.2 Data collection methods

In preparation for this project, it was important to examine which data collection methods that would be the most beneficial. Our project aimed to combine qualitative and quantitative data analysis to further increase the credibility of the discussion and conclusions drawn from the result.

When deciding which data collection method to use, it is important to consider the following factors[26]:

1. Cost
2. Number of respondents
3. Response rate
4. Number of questions
5. Control over the response situation
6. Interviewer effect
7. Complexity in question and answers

After examining all the factors above, some are more relevant or less relevant to our study. With no budget, cost was not something really to consider, the surveys would therefore be sent out through mail and transcription would be done by hand. Control over response rate was not something we could exercise. The interviewer effect can be explained as things the interviewer does, consciously or subconsciously, which influences the interviewees answers or how their answers are analysed. This is something this project tried to decrease by switching the person handling the data of the interviews and testing each other's conclusion through discussion. The number of respondents required for the study was decided when saturation had been reached, meaning the answers of the interviews feel repetitive. Low response rate could make it difficult to complete the project. When asking teachers if they were willing to participate, it was important to make it clear what was expected of them to make sure they fulfil both the survey and interview. Other factors that influence the method in this project was the number of questions and the complexity in question and answers. It was important that the survey did not feel overwhelming for the respondents and that the interviewees felt like it was designed by someone with experience of teaching that prepared both the survey and interviews.

3.2.1 Mixed mode

Mixed mode was used to combine qualitative and quantitative data analysis, the name of the method implies the use of a combination of different ways, or "modes", to collect data[27]. Investigations often use either surveys or interviews, but if the benefits outweigh the drawbacks there is no reason to not use both. This is described as mixed mode and used in this project to give the participants time to prepare some of their answers before the interview[26]. This is in hope that the focus of the interview will shift from "what" the participants think to "why" they think in a certain way and further give a deeper understanding of our results.

According to Michael W. Link an optimal mixed mode design is one that will reduce the total amount of error in the survey to the greatest extent possible[27]. This is true for any data collection mode; the important aspect is to decide which approach do it most efficiently. Since both short-answer questions and long-answer questions were needed to more easily compare upper secondary school and university mixed mode was judged to be the more optimal data collection method to use.

3.2.2 Survey

The survey was the first phase in the project and had two main goals. The first goal was to get concrete answers from the participants to gain quantitative data. The second goal was to let the participants get an overview to better prepare them for the interview that would later be conducted. Even if prioritization is something probably all teachers think about at some point, it is important that they understand their thoughts in context with this project. This is also the reason why the survey was sent out before the interviews.

In the process of creating a survey there are several factors that are important to motivate people to answer the survey. These factors are as follow[26]:

- Aesthetically appealing - The survey should give a professional and yet simple impression.
- Order and structure - The survey should be easy to understand and there should exist a clear distinction between questions.
- The order of question - The survey should have a clear red thread and previously answered questions should not affect questions later in the survey. Further it is important that the participants find the questions interesting.
- The total scope - The survey should be short and precise, and it is important to ask yourself the question "What exactly will the answers from this question be used for?" A good estimate is that a survey should take about ten minutes for the participant to execute.

These factors were considered to the extent possible. Because the survey conducted in this project was rather short, the main focus was on the total scope and our methodology question "how can the answers be used in the subsequent interviews?". These were the most important factors when creating the questions of the survey. Two slightly different surveys were created, one for upper secondary school and one for university, see Appendix 2 and Appendix 3 respectively. These were first reviewed and discussed with two independent teachers, one from upper secondary school and one from a university. After revision, the surveys were implemented.

The simplicity of a survey benefits the presentation of the results, as it reduces ambiguity otherwise present in interviews. There are two main reasons why a survey is particularly useful in this study. The first one is that the answers of the survey can easily be compared amongst each other, which makes spotting outliers a lot more straightforward. The second reason is that answers can be limited to single words or sentences, which can aid in the presentation of the results. The conducted survey will only be sent to the interviewees, as we lack the capacity to conduct surveys and interviews on a larger scale.

3.2.3 Interviews

Interviews can be used to deal with unexpected answers and explore answers from the survey with follow-up questions. The goal is to create a clear picture of the formulated problem presented in the project. This project acknowledges that there is a potential issue of being biased if the interviewer has too much information about the subject they are researching. Interviews often work optimally when the research team has little previous knowledge about the subject or when the focus is to better understand the views of other people. Interviews can further be separated into five areas[26].

1. The unexplored area - This area focuses on subjects that might be completely new with low establishment in science.

2. The human world - This area focuses on how other humans perceive the world they live in.
3. The development of theories and concepts - This area focuses on mapping, comparison between different groups and the use of earlier research.
4. The examination of theories - This area focuses on how an interview can be used to explore new territory and theories.
5. Complement to other research - This area focuses mainly on the level of ambition of the interview.

Based on these five areas and the literature study, two types of interviews were created, one for upper secondary school and one for university, see Appendix 4 and Appendix 5 respectively. These were also reviewed and discussed with two independent teachers, one from upper secondary school and one from a university. After revision, the interview templates were implemented. The interviews have many similarities but are structured differently for the two teacher groups in order to be applicable to each level. It was important that the interviews were easy to follow, capture the complexity of the answers and still left room for flexibility.

Using the answers from each individual survey as a reference point, interviews can function as an outlet to better explain and confirm the ideas and reasoning but will still make room for spontaneous questions depending on the answers of the interviewees. This is often referred to as semi-structured[28], meaning the interviews follow a template, to make every interview easier to compare but will also allow for unplanned questions of interest. The reason semi-structured interviews were preferable in this project can be summarized into two main reasons. The first reason was that the central content is meant to be interpreted by the teachers themselves, therefore context was needed to draw further conclusions about the result of the survey. The second reason was that the complexity of the subject this project tries to examine makes it impossible to predict every question of interest.

To further understand the knowledge gaps between upper secondary school and university, both open-ended and closed-ended questions need to be present. Therefore, it was of interest to not show or prepare the subjects any further for the interview as to not influence their answers. Even if the survey to some extent prepared the participants for the questions, it was still important that the interviews caught their detailed reasoning about how they prioritize the central content.

3.2.4 Selection of participants

The focus of this project was on the experience of the teachers rather than the perceived knowledge of their students. This is because it is often difficult to assess your own knowledge even if compared to others, especially when the student lacks expertise in the subject that is being assessed. With this in mind the idea was to avoid measuring knowledge amongst students and instead investigate the differences in prioritization of topics amongst teachers, and if and how it affects students. This further means that the interviews will shift between open-ended questions that will focus on discussion and closed-ended questions which will focus on reasoning behind the answers.

In the choice of participants the focus was on the Gothenburg area in general due to the easy access to teachers at both upper secondary schools and university. It was also crucial that the project did get the opinion of teachers from more than one university, which led to the involvement with Gothenburg University as well. Because Chalmers and Gothenburg University are located in Gothenburg the main part of the interviewed teachers from upper secondary school level was from Gothenburg. To represent the remaining students at the two universities, teachers from outside the region of Gothenburg were reached out to as well.

An important restriction was to not interview somebody you knew from before, for instance a previous teacher. This is in order to not influence the integrity of the interview and to force the interviewer to not take anything for granted or missing an important question due to previous knowledge about the person being interviewed. Another restriction was to stop searching for people to interview when saturation was reached, rather than aiming for a specific number of participants[26].

3.2.5 Transcription of interviews.

Transcriptions of interviews were used to create a more transparent dataset in order to highlight the answers in the interviews and further ease the analysis. We personally decided to create a number of rules to keep the same structure in our transcriptions.

- Every spoken word is written down.
- Each time a new person talks, create new section.
- The words of the interviewer are marked in red text.
- The words of the interviewed are marked in black text.
- Inputs that are not words, for instance laughter or gestures, are written inside asterisks, e.g.*laughs*

It was important that the same researcher did not do both the transcription and the interview for three reasons. The first reason was to enhance the objectivity of the transcripts by minimizing interviewer bias. The second reason was that if the interviewer were to transcribe their own interview, they may have an incentive to make the interview shorter in order to cut workload. The third and last reason was to give interviewers a better insight into all conducted interviews in the project, making it easier to discuss the results.

3.3 Analysis

Themes was established based on the transcribed interviews. Identifying a set of themes is advantageous in order to simplify the comparison of qualitative data[29]. With the answers from the interviews divided into themes it is also easier to grasp the whole picture and patterns, which should result in more credible conclusions.

The thematic method is commonly used in qualitative research and often as a complementary method to assist the analysis of a project[29]. It is a method used to examine data sets to further get a better grasp of the overall situation and trends. Thematic analysis can be described as a translator, which can work to ease the communication between the results of different research methods.

Thematic analysis can be divided into six phases[29].

1. Familiarizing yourself with your data. Here the main focus is to get a better grasp of the data and get an overall view of the general opinions.
2. Generating initial code. Here important sections of text are labelled and coded to easier review the transcribed interview.
3. Searching for Themes. Here identified labels in phase two are used to find themes which occur across all data.

4. Reviewing themes. Here the themes are examined to find coherence amongst them. The individual themes will also be reviewed in order to examine if the theme can be used to represent the overall data or if it can fit in with another theme.
5. Defining and naming themes. Here the researcher decides what the themes represent in the data and why the themes are interesting to examine.
6. Producing the report. Here the focus is to produce a coherent analysis that for a critical reader would make sense. This means that every theme can be easily understood and motivated from the original data set.

There are a lot of advantages regarding analysis using themes. Firstly, it is a flexible method, meaning it can be altered to fit different needs based on what study you want to conduct while still providing a broad and complex analysis. Secondly this method is accessible, meaning it is easy to learn, does not require any technological knowledge and does not require a vast amount of data. Lastly, it is a useful way of summarizing key features and creating a better overall picture of data[29].

When doing analysis using themes it is important to consider that there are some disadvantages with this type of analysis. Firstly, it is important to understand that thematic analysis is not as well developed compared to other scientific analysis methods, and therefore lacks a lot of supporting literature. This is the main reason why in this project we elected to use a survey to strengthen the method. Secondly even if the analysis is easy to learn it is a complicated analysis to master, meaning that it takes time to both learn how to find themes and also develop the ability to find correlation between different data sets. Lastly even if the flexibility is mostly a positive factor with the analysis it can lead to inconsistency. In this project we intended to avoid this by both being more than one person searching for themes but also comparing themes over the course of the analysis[29].

4. Results and Discussion

This chapter presents the result from both the survey and interviews and overall themes found in the analysis of them. These findings are discussed individually for each part of chapter 4, followed by an overall discussion to try to answer the research question of this project.

Chapter 4 contains five parts:

- Prioritization of topics in chemistry at both levels
- What students find difficult in chemistry, according to teachers
- University teachers' opinions on undergraduates' lack of knowledge
- The opinion of teachers at upper secondary school on the curriculum
- Other themes found

4.1 Prioritization of topics in chemistry at both levels.

Below follows the result from both the survey and the interviews of the prioritization of the central content in *Chemistry 1* and *Chemistry 2* by both groups of teachers. Further themes found in the interviews surrounding these prioritizations will also be presented. Lastly discussion of these findings will be discussed.

4.1.1 Prioritization of topics in *Chemistry 1*

Here are the results from the prioritization in Chemistry 1 by upper secondary school (Figure 1) and university teachers (Figure 2), followed by a paragraph comparing them.

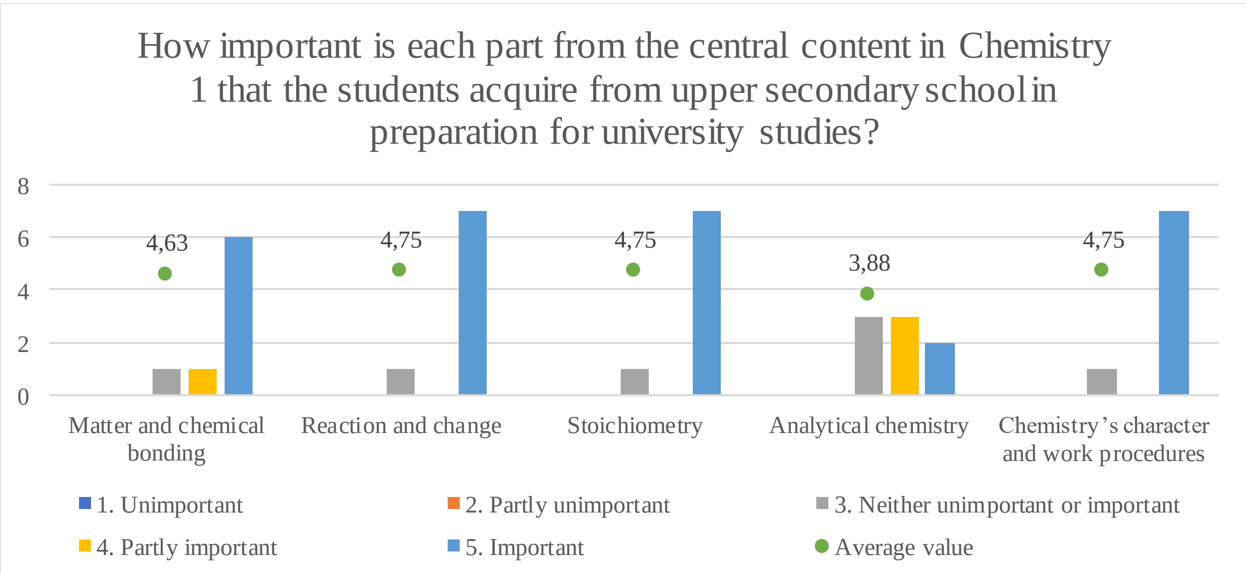

Figure 1. Result of survey question for upper secondary school teachers: How important is each part from the central content in *Chemistry 2* that the undergraduates acquire from upper secondary school in preparation for university studies?

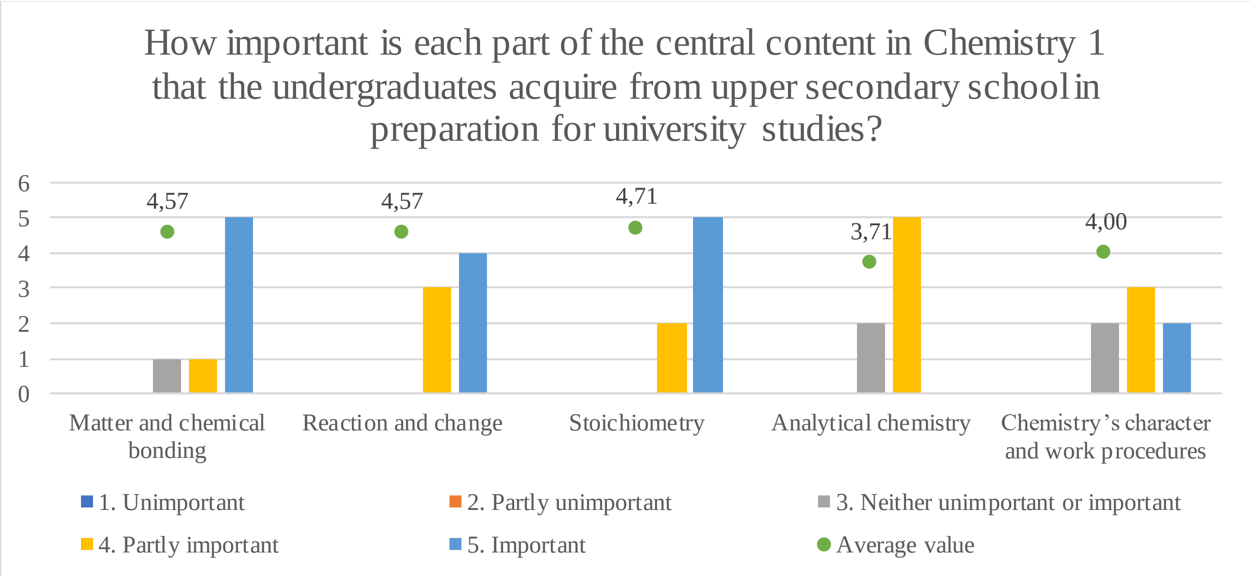

Figure 2. Result of survey question university teachers: How important is each part of the central content in *Chemistry 1* that the undergraduates acquire from upper secondary school in preparation for university studies?

Based on a comparison of the mean values, university and upper secondary school prioritize Matter and chemical bonding, Reaction and change, Stoichiometry and Analytical chemistry similarly. Among these Matter and chemical bonding, Reaction and Change and Stoichiometry were prioritized higher for both groups of teachers. Analytical chemistry was less prioritized by teachers at both levels compared to the other topics. The prioritization of Analytical chemistry was also more scattered amongst teachers at upper secondary school, see figure 1. The most significant difference between upper secondary school and university teachers is visible in the prioritization of Chemistry's character and work procedures. Which was more scattered amongst teachers at university, see figure 2.

4.1.2 Prioritization of topics in *Chemistry 2*

Figure 3 show and 4 respectively show the results from the prioritization in Chemistry 2 of upper secondary school and university teachers. Followed by a paragraph comparing them.

Upper secondary school

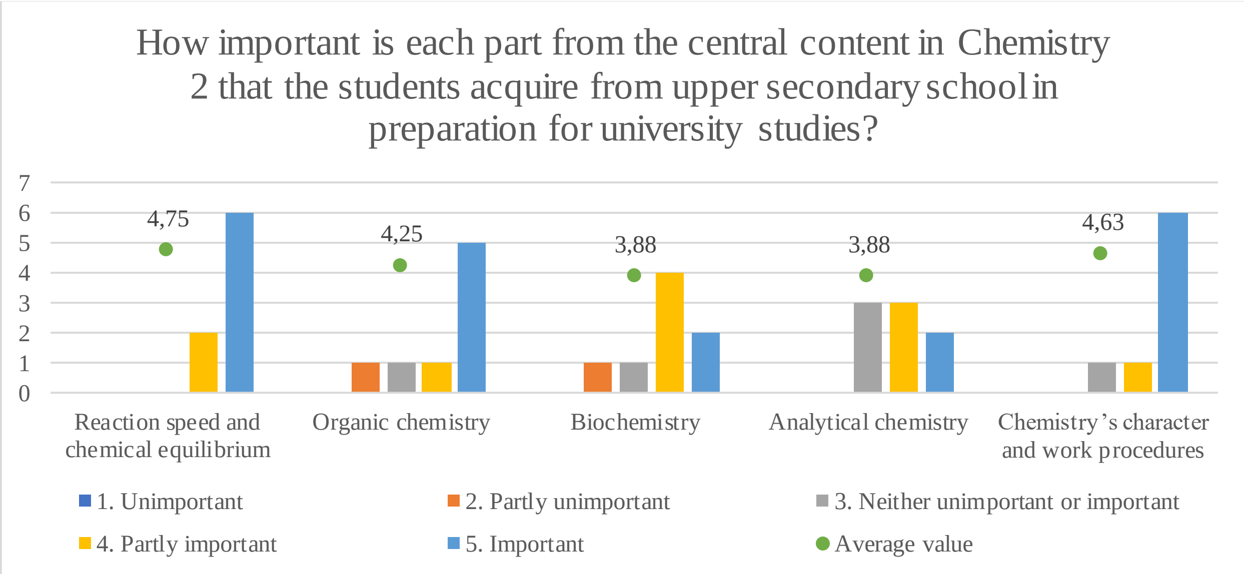

Figure 3. Result of survey question for upper secondary school teachers: How important is each part from the central content in *Chemistry 2* that the students acquire from upper secondary school in preparation for university studies?

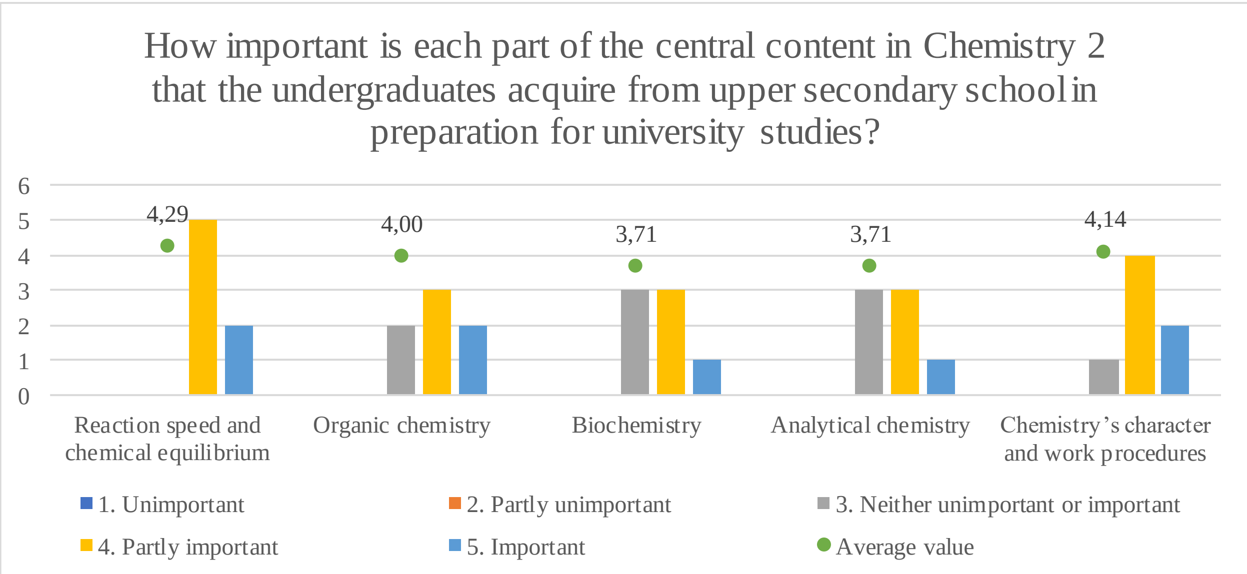

Figure 4. Result of survey question university teachers: How important is each part of the central content in *Chemistry* 1 that the undergraduates acquire from upper secondary school in preparation for university studies?

Based on a comparison of the mean values, university and upper secondary schools prioritize Organic chemistry, Biochemistry and Analytical chemistry similar. It should be noted that the largest difference in prioritization is found between colleagues at both level, as their opinions on how to prioritize Organic chemistry, Biochemistry and Analytical chemistry vary most within each group. There are two significant differences between upper secondary school and university teachers regarding *Chemistry 2*, which is the prioritization of Reaction speed and chemical equilibrium and

Chemistry's character and work procedures. University teachers prioritized both Reaction speed and chemical equilibrium and Chemistry's character and work procedures lower than upper secondary school teachers do.

4.1.3 Themes found about prioritization in *Chemistry 1* and *Chemistry 2*

Themes found in interviews in context with the survey will be presented below and then further discussed.

A difference in opinions on chemistry's character and work procedures between upper secondary school and university

Comparing the prioritization of character and work procedures in the survey for both *Chemistry 1* and *Chemistry 2* it is shown that upper secondary school and universe have different opinions.

Teachers at upper secondary school prioritized chemistry's character and work procedures high for both *Chemistry 1* and *Chemistry 2*, this can be seen both in the answers of the survey as well as in comments during interviews. During some of those interviews it was mentioned that chemistry's character and work procedure according to them was the main goal for students to develop and also to give students a more general education. Interviews also pointed out the importance of students understanding and being able to communicate through reports to prepare them for university. The importance of planning, performing and analysing experiments through a report in the context of chemistry's character and work procedures was also brought up during interviews.

At the university level, the opinions of the teachers regarding Chemistry's character and work procedures were more diverse, as can be seen in the result of the survey (Figure 2, 4) as well as from comments in the interviews. Some teachers thought that it was important for students that did not continue with their chemistry studies to have a chance to encounter chemistry's character and work procedures, to get a better general education. Other teachers thought that it was not as important for students at upper secondary school, because interested students would encounter chemistry's character and work procedures if they continued with their studies in chemistry and also did not see the benefits for students that would not. Several teachers also mentioned that they did not understand completely what chemistry's character and work procedures meant in the context of the central content but points out that they think performing experiments is important. One teacher also mentioned the importance of using experiments to support the learning process.

Analytical chemistry is prioritized lower

Analytical chemistry was overall prioritized the lowest at upper secondary school, see Figure 1 and 3. During interviews, several teachers mentioned that analytical chemistry was not as important and that they address the topic briefly. Some teachers mentioned that they focus more on analytical chemistry in *Chemistry 2* compared to *Chemistry 1*. An important aspect that was brought to attention during interviews was that several teachers mentioned that the lab equipment that the school could provide affected the amount of analytic chemistry the teacher was able to teach.

Likewise at university level, analytical chemistry was prioritized lower in *Chemistry 1* compared to the other parts of the central content and prioritized about the same as other parts of the central content in *Chemistry 2*, see figure 2 and 4. Teachers at university mentioned that analytical chemistry is not fundamental for understanding chemistry as a whole and that students get a substantial dose of it at university. Several teachers thought that analytical chemistry is hard for students to understand without a solid basis of chemistry knowledge and therefore that analytical chemistry is both complicated and less important to teach at upper secondary school. A teacher pointed out that you should not engage in analytical chemistry on the expense of other parts of the central content in either course.

Basics in chemistry is required for further learning

Throughout interviews teachers mentioned basic chemistry knowledge as an important part of understanding and preparing students for chemistry at a higher level. This can be reflected in the prioritization of Matter and chemical bonding at both levels as well as Reaction and change to some extent.

Teachers at upper secondary school mentioned that they put a lot of focus on chemical bonding in *Chemistry 1*. Several teachers mentioned that Matter and chemical bonding takes up a lot of time, pointing out the importance of the periodic table and aggregation states. A teacher commented that if the students did not understand chemical bonding or the periodic table, they would not be able to apply stoichiometry or understand any kind of chemical calculations.

University teachers thought, as mentioned before, that chemical knowledge about matter, chemical bonding and reactions are important basics for understanding chemistry at a higher level. Several teachers mentioned that chemical bonding is central in a chemical perspective, even if universities address it starting at a basic level when students continue their studies in chemistry. Some teachers compared basic chemistry knowledge with chemistry's character and work procedures, saying that basic knowledge is more important than students understanding how chemists work.

Understanding chemical calculations improves student comprehension of chemistry

Teachers at upper secondary school mentioned that mathematics was an important part of their way of teaching and this can be reflected in that the prioritization of three topics: Stoichiometry, Reactions speed and chemical equilibrium and Reaction and change are amongst the highest, see Figure 1 and 3. Teachers commented that they put extra focus on the mathematical parts in the chemistry course and that stoichiometry was essential for further studies in chemistry, further saying that without the understanding of calculations within chemistry the students would be unable to conduct experiments. Several teachers mentioned that it is more important to understand the mathematical aspect of chemistry for higher studies rather than memorizing knowledge. One teacher pointed out the importance that chemistry teachers see stoichiometry as a pillar in their teaching which is essential for students to learn in both *Chemistry 1* and *Chemistry 2*.

Similarly, teachers both at upper secondary school and university mentioned that mathematics was an important part for student preparation for higher education in chemistry. Stoichiometry and Reaction speed and chemical equilibrium were the two highest prioritized parts of the central content in each course, see Figure 2 and 4. Several teachers mentioned that stoichiometry is an important basis for students to understand chemistry. One teacher pointed out that stoichiometry is not taught at university, so it is important that students have a solid grasp of it after completing upper secondary school.

Divided opinion on Organic chemistry and Biochemistry

The prioritization of Organic chemistry in *Chemistry 2* was rather diverse between upper secondary school teachers, see Figure 3. Several teachers mentioned that Organic chemistry is a large part of *Chemistry 2* and thus focuses on that topic. One teacher believes that Organic chemistry is of interest to another type of students in the class rather than the usual group of chemistry-interested students. In contrast, several teachers mentioned that Organic chemistry requires a great deal of time in *Chemistry 2* at the expense of Reaction speed and chemical equilibrium and applying mathematics to chemistry. In the context of Organic chemistry, Biochemistry was often mentioned. The opinion on Biochemistry was also diverse amongst teachers as displayed in Figure 3. Some teachers mentioned that Biochemistry, even if it was less important overall, is still a valid part of *Chemistry 2*. Other teachers mentioned that Biochemistry was less important because it would be introduced at university if the student continued studying chemistry. One teacher also mentioned that if a student arrived at university without any knowledge in Biochemistry the student would probably still manage just fine.

Teachers at university prioritized Organic chemistry and Biochemistry similar to teachers at upper secondary school, see Figures 4 and 3. According to the survey and interviews there was still a disparity in the prioritization of the university teachers. Teachers commented that it is important for students to know some Organic chemistry and that it should be prioritized over Biochemistry. Some teachers mention that they prioritized Organic chemistry higher because of their own background. Other teachers pointed out that they felt that Organic chemistry and Biochemistry is difficult to teach to students at a basic level, however that it can be beneficial if used as a source of interest for chemistry.

4.1.4 Discussion

Below follows a discussion of findings surrounding the prioritization of central content based on the figures and themes found in chapter 4.1. This project has studied the opinion of teachers whether certain topics are important to teach or not. However, we have not touched on the subject of what teachers at upper secondary school are obligated to follow, referring specifically to the grading requirements. It is important to mention that mean values presented in the Figures 1 to 4 can only be compared to other mean values in the same figure. Even if two mean values are the same for the different groups of teachers it does not mean they are prioritized the same for the two groups. It is important to mention that it was not prohibited for teachers to rank all topics the same. From the results a lower overall mean value of university teachers' opinions can be observed in comparison to upper secondary school teachers in the survey, which suggests university teachers ranked the topics with more caution. It might also indicate that upper secondary school teachers have a more thoughtthrough opinion on prioritization in comparison to university teachers. This is very likely due to only upper secondary school teachers being required to have knowledge of them.

To comprehend chemistry students need the basics of chemistry.
This statement is no way controversial, that the basics is needed for deeper learning in any kind of subject is probably a statement most people would agree on. The difficult part is instead to define what the basics are. Important discussion such as what topics should be included in further how much of each topic should be categorized as the basics of chemistry. Basic chemistry for a university teacher and for an upper secondary school teacher or even a lower secondary school teacher is probably quite different from each other. Here an argument could be made that students

that reach a grade of E[30] should have enough basics in chemistry for higher education, but as mentioned from several teachers that students with the grade E will probably have a lot of problems studying at university. In addition to this observation, university teachers that had experience with the central content mentioned that there were almost no specific mentions about basic knowledge students would acquire during *Chemistry 1* or *Chemistry 2*. This could be a question about how teachers interpret the central content, therefore we think it is important that chemistry teachers engage in discussion to define what basic knowledge in chemistry is.

Understanding chemical calculations improve student comprehension of chemistry

It is clear that teachers at both levels think it is important for students to know mathematics in order to comprehend chemistry, because so many topics in chemistry require mathematical calculations to be useful. Particularly important is that students have knowledge of stoichiometry, which in itself requires students to possess a certain level of mathematical ability, since it is not covered at university level. A previous American study[8], see chapter 2.1, has shown that knowledge in stoichiometry and mathematics are significant predictors on how well the student performs at university level, their conclusion is further supported by our findings indirectly through how teachers at both levels prioritize these topics.

Chemistry's character and work procedures

The reason why most upper secondary school teachers revere the topic of Chemistry's character and work procedures seem to be how it translates into general knowledge and practical skills, such as conducting experiments and communicating chemistry by writing reports. It seems that teachers at upper secondary school utilize this topic to confirm the knowledge students possess and hence prioritize it higher than some other topics in both courses.

At university level, teachers had differing opinions on the topic of Chemistry's character and work procedures. Since the topic is not named after any classic chemistry theme, there is a possibility that teachers at university have not heard of this topic before and expect it to include what it is in its name literally. Going by its name the topic may seem rather fuzzy and undefined. Under the assumption that the topic involves conducting experiments, which it does, several university teachers found it important. This also gives reason to believe that some of the responses from university teachers in the survey could be based on insufficient knowledge of what the central content actually contains.

The use of Analytical chemistry at upper secondary school

Analytical chemistry is an interesting topic in our study because both groups overall prioritized it the lowest. A logical discussion is then if analytical chemistry is even necessary at upper secondary school, which is a difficult reform to make because such a change would revamp the whole course nation-wide. Instead, another interesting discussion is what to do with analytical chemistry in its current state. It is important to mention that analytical chemistry is a small part of *Chemistry 2* and even smaller for *Chemistry 1*, but still a substantial one. From the interviews, it is clear that school equipment is an important determinator on what teachers can do in analytical chemistry. Furthermore, a majority of teachers just rush through the topic of analytical chemistry to have time for the other parts of the central content. Based on our study, we think that it could be beneficial to use analytical chemistry as a way to increase collaboration between upper secondary school and university through study visits. If done correctly, it could benefit both levels of education. Upper secondary schools would get to learn from better equipment and seeing how one works with chemistry, their course would probably get more relevance among students. Universities would benefit in that more students would feel more familiar to the university but also that, if done successfully, the number of students interested in chemistry overall would increase, which is beneficial for the growth of the universities. It is important to mention that not all upper secondary schools have easy access to a university, but this could probably be solved with presentation and discussion through digital means.

Approach to Organic chemistry and Biochemistry

This is a difficult subject to discuss because the opinions are so diverse amongst teachers. For this reason, we restrict us to two main points of discussion. Firstly, in what way should Organic chemistry and Biochemistry be presented to the teacher community by the Swedish National Agency for Education. If the opinions about these two subjects are split amongst current teachers, it can create an even bigger problem for newly graduated teachers. One could make the argument that that is what the national course test is for, but as mentioned throughout interviews several teachers mentioned the low level of chemistry and the unbalanced distribution of the central content. Even if the central content only contains two paragraphs for Organic chemistry it is clear from several teachers that it takes up a lot of time in *Chemistry 2*. It should be beneficial for teachers overall if these parts of the central content were more clarified.

Secondly, how much Organic chemistry and Biochemistry should be present in *Chemistry 1* and *Chemistry 2*? As presented previously a teacher mentioned that some Organic chemistry could be relevant for *Chemistry 1*. This could create a clear goal throughout the chemistry course but as mentioned by several teachers *Chemistry 1* is already too packed. Further some teachers would make the argument that Organic chemistry and Biochemistry is less relevant for students only studying *Chemistry 1*, because it is too complex to comprehend at such an early state in chemistry studies. That reverts back to the situation teachers is in today, that a large part of *Chemistry 2* is Organic chemistry. As mentioned before several teachers approach *Chemistry 2* as a testing ground for different branches in chemistry. Therefore, it could be beneficial if every part of *Chemistry 2* were roughly of equal size. For example, if Organic chemistry took less space, parts like physical chemistry could get a chance to be further explored, or other topics of interest. It is also important to mention that some teachers thought Organic chemistry was important for students who would continue to higher education. The specifics surrounding Organic chemistry itself would be extremely interesting to investigate further but hard for this project to cover.

4.2 What students find difficult in chemistry, according to teachers

To examine knowledge gaps amongst students the survey contained a free-text-question about what the teachers thought the students struggled with at their respective level of teaching, see Table 1 and 2.

4.2.1 Teachers at upper secondary school

In the survey, upper secondary school teachers were asked the questions about what they thought students found difficult in chemistry at the level of upper secondary school, see Table 1.

Table 1. Compilation of free-text answers from survey, upper secondary school teacher's opinions on student difficulties in chemistry

What do students usually find difficult in chemistry at upper secondary school?	
Topics mentioned at upper secondary school.	Frequency
Stoichiometry	7
- *Amount of substance & molar ratio*	3
- *Mathematics in chemistry**	2
Chemical Bonding*	3
Organic chemistry*	2
Link chemistry to everyday life	1
Laboratory work	1
Oxidation state	1
Acids & Bases	1
* Topics mentioned at both levels	

From the survey there were three categories that were mentioned more than once. The most frequently mentioned difficulty according to the upper secondary school teachers were stoichiometry which included answers related to mathematics in chemistry, substance and molar ratio. The survey had comments like students having difficulties comprehending concepts like molar ratio and amount of substance. From the interviews there are several mentions regarding students finding it difficult to apply mathematics in the context of chemistry. Other examples of this were stoichiometry being difficult and taking a long time for students to learn, and also mathematics related to chemical equilibrium in *Chemistry 2* being hard for students to grasp.

The second most mentioned difficulty was chemical bonding. The survey had comments surrounding students having a hard time understanding the difference between intermolecular bonding and intramolecular bonding and also how to apply these two concepts further. From the interviews there were similar mentions surrounding students struggling with applying the concepts of chemical bonding in different contexts.

The third most mentioned difficulty was Organic chemistry. In the survey comments were restricted to just mentioning Organic chemistry. In the interviews teachers just confirmed Organic chemistry being a larger part of *Chemistry 2* and students having difficulties with it.

The remaining difficulties were mentioned only one time and can be summarized as follows.

- Link chemistry to everyday life. Here the teacher mentions that it is problematic for students to apply chemistry to their everyday life and that students have a hard time connecting different parts of chemistry together.
- Laboratory work is also mentioned in that students are not used to it.
- Oxidation state and Acids & Bases are both mentioned as concepts that students have a hard time grasping.

4.2.2 Teachers at university

In the survey, university teachers were asked the questions about what they thought students found difficult in chemistry at the level of university, see Table 2.

Table. 2 Compilation of free-text answers from survey, university teacher's opinions on student difficulties in chemistry

What do undergraduates find difficult in chemistry at university?	
Topics mentioned at university	Frequency
Chemical Bonding*	6
- *Quantum Theory, Orbitals and hybridization***	3
Mathematics in Chemistry*	4
- *Problemsolving*	1
- *Dimensional analysis*	1
Thermodynamics**	2
Kinetics	1
Qualitative reasoning	1
Organic chemistry*	1
Computer skills	1
* Topics mentioned at both levels	
** Topics within the subject Chemistry but not of the central content of the courses *Chemistry 1* or *Chemistry 2*	

For university teachers there were three categories that were mentioned more than once in the survey. The most frequently mentioned difficulty according to the university teachers was chemical bonding, which included answers related to quantum theory, orbitals and hybridization.

From the interviews there were comments about students missing or struggling with the concept of chemical bonding, on the other side one teacher mentioned that students normally understand the most common types of chemical bonding.

The second most mentioned difficulty among university teachers was mathematics in chemistry which included problem solving and dimensional analysis with teachers mentioning the students have problems applying mathematics also on other subjects. From interviews there were statements surrounding undergraduates struggling with mathematics in the first chemistry course as well as just lacking basic mathematical knowledge.

The third most frequently mentioned difficulty was thermodynamics. From interviews, one teacher mentioned that several of their students over the years had told them that thermodynamics was one of the most difficult things they have encountered. Teachers mention that thermodynamics is abstract and hard for undergraduates to grasp. A difficulty that was not brought up in the survey but was prevalent in the interviews was the ability of the students to comprehend and apply a scientific way of thinking. Interviews mentioned that students have a hard time accepting that there is no perfect answer to every question and that models are just ways to describe the phenomenon, not the actual truth.

The remaining difficulties were mentioned one time and can be summarized as follows.

- Quantitative reasoning, interviewee commented that undergraduates had difficulties with everything surrounding quantitative reasoning.
- Computer skills, interviewee mentioned programs such as Microsoft Excel.
- Organic chemistry, interviewee mentioned examples such as Lewis structures.
- Kinetics was mentioned in the survey but not expanded on further.

4.2.3 Discussion

When discussing the issue of difficulties, it is important to mention that they can be different for each student, this is one of the reasons why it is more interesting to ask teachers what they experience students having difficulties with. Another reason is that students often do not understand what actual knowledge they lack because they often do not possess the whole picture. Asking a person with relatively low actual knowledge a question in a subject of which they have high perceived knowledge, a student can claim something is easy without knowing they have not understood the phenomenon they are talking about, making them misinformed. It is also important to mention that teachers cannot notice everything students struggle with but will remember those cases that they encounter more frequently.

The difficulties of Chemical bonding

As told by many teachers, a lot of students struggle with chemical bonding at both upper secondary school and university. A reason for this can be that it is just a difficult subject to teach at both levels and the use of models, like orbitals and Bohrs atom model, is prevalent, which students struggle with. An argument here could be that it is the role of upper secondary school to prepare students for university and to ease the transition. The counterargument against this is that nowhere in the central content are there mention about orbitals which is the preferred model used at university. Chemical bonding is also one of the first things university teachers teach which can be a reason why they think it is something students struggle with. This gap between upper secondary school and university might be one of the reasons why both levels of education have the feeling they got to start from scratch when they get new students and undergraduates.

The difficulties of Stoichiometry and mathematics

Mathematics and stoichiometry are often mentioned in the same instance and they are both present in what teachers address that students find difficult. This does not mean that there is a gap of chemistry knowledge between upper secondary school and university, it rather means that some students clearly lack the mathematical skills that are needed for chemistry. Also, even if a student understands mathematics to a high enough level, there are still comments from teachers about students not being able to use these skills in the context of chemistry. It is therefore important for both levels of teachers to be aware and explain to students why certain mathematics is used in chemistry and also what instance it can be applied.

The difficulties of dimensional analysis

Dimensional analysis could be seen as a subgroup to stoichiometry. Here there is a need for a broader approach, meaning that all the subjects of natural science should have some responsibility to teach and use dimensional analysis. This does leave out whether it would be beneficial for students to understand dimensional analysis or not, but we believe dimensional analysis would help students to understand stoichiometry more efficiently.

The difficulties of Organic chemistry

Organic chemistry was mentioned at both levels in the survey, but due to its prioritization amongst teachers being so diverse as well as the topic was mentioned only once at each level in the survey, there is no need to discuss it in this section.

The difficulties for Thermodynamics

Thermodynamics is mentioned as being difficult for students by two university teachers, but it is important that nothing is mentioned about thermodynamics in the central content of chemistry at upper secondary school. This does not take away that undergraduate struggle with thermodynamics. As it stands right now, the universities have the main responsibility for teaching it. Here a solution could be to add some more thermodynamics into *Chemistry 2*, maybe in exchange for some Organic chemistry due to its low priority of many teachers, but it could also be the case that students at upper secondary school would not be ready to learn thermodynamics and that it would be even more of an obstacle.

4.3 University teachers' opinions on undergraduates' lack of knowledge

University teachers answered the following question in the survey: What do you feel undergraduates lack in chemistry when they start at the university? See Table 3. Many teachers mentioned knowledge which can be described as fundamental knowledge of chemistry, including knowledge of chemical bonding, kinetics, knowledge of models, laboratory skills and thermodynamics. Two teachers mention in their interviews that it is obvious that undergraduates have not been taught orbitals, hybridization nor quantum theory. Another explains that it would be beneficial for undergraduates to have learned about entropy when it comes to thermodynamics. One teacher questions the way students are graded in upper secondary school, as the requirements do not specify what specific knowledge the student actually should have learnt. Other things teachers think undergraduates lack in fundamental knowledge of mathematics and physics, motivation, curiosity and good study habits.

In the survey, university teachers were asked the questions about the courses *Chemistry 1* and *Chemistry 2*, whether they believe something is missing to prepare the students for higher education, see table 3.

Table 3. Free-text answers from the survey, topics which undergraduates lack when they start university, mentioned by university teachers.

What do you feel undergraduates lack in chemistry when they start at the university?	
Topics mentioned at university	Frequency
Fundamental knowledge of Chemistry	7
- *Chemical Bonding*	2
- *Kinetics*	1
- *Knowledge of models*	1
- *Laboratory skills*	1
- *Thermodynamics*	1
Fundamental knowledge of Mathematics and Physics	1
Motivation	1
Curiosity	1
Good study habits	1

In the interviews, several teachers at the university level shared their views of which field of chemistry is taught at upper secondary school. Several teachers mention how they hope chemistry at upper secondary school cultivates interest for the subject, for example by putting the topics into everyday context. Several teachers also described their view over there being two courses of chemistry at upper secondary school. Teachers at Chalmers think *Chemistry 2* can be more explorative and light-hearted since Chalmers only requires undergraduates to have read *Chemistry 1*.

Another teacher thinks *Chemistry 2* should allow students to try out the different types of chemistry. One teacher views *Chemistry 2* as a specialization course and believes laboratory work to be important to practice.

University teachers were also asked in their interview about what they believed their undergraduates had sufficient and insufficient knowledge of as they started their higher education. Their responses were as follows. One teacher believes the largest problem is insufficient basic knowledge in chemistry and not enough mathematical knowledge. Another teacher mentions how undergraduates come to university with problematic misconceptions that must be corrected at university, giving an example of undergraduates believing entropy is disorder. Another teacher thinks their undergraduates are missing knowledge about chemical bonding and its different models and would like students at upper secondary school to have learnt more about them beforehand, as it would only benefit them once at university. Another teacher mentions undergraduates lacking computer skills, which has been handled by giving extra lectures on it.

University teachers also mentioned that there were several things they were satisfied with. One university teacher is of the opinion that their undergraduates' prior knowledge is sufficient in general. Two teachers believe that their undergraduates have the mathematical knowledge necessary for the introductory course in chemistry and another teacher believes the mathematical knowledge of undergraduates have been the same at their university for the last 20-30 years. Another teacher says they were pleasantly surprised by how much stoichiometry the undergraduates have learnt from upper secondary school. One teacher says that their undergraduates usually have knowledge of the most common chemical bonds, such as van der Waal, covalent and ionic bonding. Another teacher commends their undergraduates for being able to follow recipes and know things by heart, such as redox chemistry and balancing reactions.

4.3.1 Discussion

Fundamental knowledge is mentioned several times but in different forms. One of these is knowledge of chemical bonding which students lack when they come to university, which has been mentioned many times throughout our report and therefore an important topic to discuss. This can depend due to several reasons, as mentioned in context with difficulties, the presentation and use of models could be a large factor here. Another reason could be that students struggle with chemical bonding in general being an important factor. It is important to understand that many secondary school teachers teach chemical bonding similar to university but that those teachers often have to adapt to the students with the lower knowledge in the group. Similarly, teachers adapt when lower secondary school students start studying at upper secondary school.

Another topic which university teachers think new undergraduates lack was laboratory skills, mentioned as important by several teachers and therefore interesting to discuss when mentioned amongst difficulties. One factor why students are less skilled in laboratory work could be that schools often do not have the right equipment to allow teachers to be flexible in their experiments. This could lead to laboratory work being too structured and leave little room for adapting experiments to the interests of students. There were comments about students from lower secondary school that never even had seen a chemistry lab before they started upper secondary school, which only give teachers a maximum of two years to both introduce and teach students laboratory skills.

Motivation, curiosity and good study habits seems to be a problem in the school system overall. Some teachers mentioned the fact that more students are being accepted into universities will lead to a group of students that are less motivated. Students lacking curiosity could be a by-product of the structure of our school system or it could just be a cultural thing surrounding students' approach to scientific research.

4.4 The opinion of teachers at upper secondary school on the curriculum

In the survey, upper secondary school teachers were asked the question about the courses *Chemistry 1* and *Chemistry 2*, whether they believe something is missing to prepare the students for higher education or not, see table 4. A substantial number of teachers feel that they need more time to teach chemistry. This opinion was also raised in several interviews, where it was explained that the issue lies specifically within the course *Chemistry 1*, as it has a lot of varying topics to cover. One teacher describes feeling a lot of stress teaching *Chemistry 1* and that their students do not get time to process the varying topics taught in the course. Three of the teachers think the course should account more hours into its syllabus, where two of these teachers suggest the course be made 50% longer to have enough time. One teacher feels that the topic of metals and electrochemistry does not get as much attention as it should, explaining in the interview that those topics are important and necessary for the students to have knowledge of. One teacher feels that the topic of gases is missing from the two courses in chemistry, explaining in the interview that the courses focus too much on Organic chemistry at its expense. One teacher believes links between chemistry and everyday life is missing from the courses, describing in the interview how important it is to find use for chemistry in everyday life, as to make students scientifically literate.

Table 4 & 5. Free-text answers from the survey: what teachers at upper secondary school think is missing and what should be reorganized in the courses *Chemistry 1* and *Chemistry 2*.

Do you think something is missing in *Chemistry 1* or *Chemistry 2* in preparation for higher education?	
Topics mentioned at upper secondary school.	Frequency
Need more time to teach	4
Metals and Electrochemistry	1
Gases	1
Link chemistry to everyday life	1
Nothing missing	1

Do you think that any or some parts of *Chemistry 1* and *Chemistry 2* should be reorganized?	
Topics mentioned at upper secondary school.	Frequency
Introduction to organic chemistry in Chemistry 1	2
Too much biochemistry and organic chemistry in Chemistry 2	1
Clear guidelines on when to teach acids and bases	1
Redundant with reaction mechanisms in Chemistry 2	1
No	1

Another question in the survey asked upper secondary school teachers if they believed that any parts of the courses *Chemistry 1* and *Chemistry 2* should be reorganized, see table5. Two teachers mentioned in the survey that Organic chemistry should be introduced earlier, already in *Chemistry 1*. It was explained in the interviews, a teacher pointed out how students at the Technical programme usually only study *Chemistry 1*, which does not include Organic chemistry, but that it should. Another response from the survey and interviews was that there is too much Organic and Biochemistry in the course *Chemistry 2*. Several teachers mention how a lot of the Biochemistry in *Chemistry 2* is already covered in the course *Biology 2* and another teacher mentioning there are other more important topics to cover than Organic chemistry such as gases, reaction rates and chemical equilibrium. Another teacher mentions that Umeå University has a lot of sway over knowledge assessment material in chemistry (aid in grading students more equally nation-wide) and believe that they have many biochemists or biologists. Within the survey, one teacher mentioned that they would like clear guidelines on when to teach acids and bases. The teachers explained further that they struggle with making it fit in well in either course as it stands now. Another teacher found it redundant teaching about organic reaction mechanisms in *Chemistry 2* and explains that teaching the students general Organic chemistry would suffice.

Opinions on the curriculum.

Many teachers talk about their discontent of the course syllabi in chemistry at upper secondary school. It is mentioned that the central content, even if reworked since 2011, is still about the same as many years before and thinks it should be modernized. An issue that teachers have is that the course *Natural Science* gives a more general education than *Chemistry 1* alone does. This becomes an issue when students are not taking *Chemistry 2*, often due to their choice of programme. In contrast, one teacher thinks it is unnecessary to study *Chemistry 2*, even if you are planning to study chemistry at university level. That is, according to said teacher, due to the fact that the topics covered in *Chemistry 2* will be covered at university level in a more qualified context. Several teachers believe there is too much Biochemistry being covered at upper secondary school and not enough about metals, electrochemistry or dimensional analysis. Another teacher finds the grading rules to be incoherent, as students need to reach A-level in every knowledge requirement, yet teachers are supposed to take the students development of knowledge over time into account as well.

Even if several upper secondary school teachers are unsatisfied with the syllabi in *Chemistry 1* and *Chemistry 2*, there are also teachers who are satisfied with them. One teacher mentions that the syllabus in *Chemistry 2* is well proportioned timewise and several teachers believe students are well prepared for higher studies in chemistry if they read both Chemistry 1 and Chemistry 2 as they stand today. Several teachers also mention the leeway the current central content allows for, telling how useful it is and how thankful teachers are for it. The teachers describe how they use the leeway to delve deeper into subjects, to make the courses well rounded on their own accord. Another comment about the leeway within the central content is how useful it is as it allows for teachers to focus on creating interest for the subject. As one teacher describes the leeway within the syllabi: that it is not as important that teachers structure the courses the exact same way as if you believe in your structure yourself because that will be evident to the students and they will do better.

Other viewpoints from upper secondary school teachers

Several teachers also mention in their interviews how some parts of exams and other knowledge assessment material distributed by the Swedish National Agency for Education do not test students at a high enough level to prepare for higher studies in chemistry. A couple of teachers explain how students will likely have a difficult time studying chemistry at university level if they only achieve the lowest passing grade of E.

Many upper secondary school teachers also shared very differing opinions on the curriculum. One teacher views *Chemistry 1* to be the course to cover fundamentals and *Chemistry 2* as a continuation course to apply those fundamentals. This teacher continues by mentioning how *Chemistry 2* is more dependent on the materials and equipment supplied by their school than *Chemistry 1*. Another teacher has a similar opinion on *Chemistry 1* covering the fundamentals but finds *Chemistry 2* redundant and the mathematics used in *Chemistry 2* was only taught at university level when the teacher went to university 30 years ago. The same teacher thinks the Swedish school system has forgotten that practise makes perfect. Another teacher believes *Chemistry 2* to be too similar to *Biology 2*. Yet another teacher finds it an issue if other chemistry teachers do not focus primarily on teaching stoichiometry and other crucial parts of *Chemistry 1* and *Chemistry 2*. Another teacher thinks it would be a good idea to let chemistry be a subject for students to learn even at a young age and not start only at lower secondary school, giving an example of the amount of substance being taught early on. One teacher thinks chemistry as a school subject requires a lot more time and effort from students in comparison to other subjects they read. The same teacher also mentions how two teachers at upper secondary school may focus differently and an issue of one group of students being more prepared for higher studies than the other arises.

4.4.1 Discussion

The leeway within the curriculum

The leeway which the curriculum allows for is appreciated by many teachers. The leeway allows teachers to "correct" the syllabus to a certain extent and to focus on what they are passionate about. As one teacher also mentioned, the leeway allows the teacher to tailor the course for certain programmes and groups of students. As this study aims to find a specific prioritization of course topics which will prepare students the best for higher studies, this leeway may allow teachers to use such a prioritization without requiring any changes of the official curriculum. However, the leeway cannot be used to change or ignore any topics that are defined in the central content, as teachers are obligated to teach those topics to some extent and also grade students accordingly. Since teachers mentioned a lack of time teaching the course *Chemistry 1*, due to the amount of content required to teach, the leeway can only help to alleviate the workload to a certain extent, if any. As many teachers suggest, increasing the number of hours the course counts for could be a solution, considering it is a lot of content to cover. Such a change has been made before, as the course would have the same number of hours as the course *Physics 1a*[31], which is also often taught to the same year and programmes at upper secondary school as *Chemistry 1*. This change would however be made and decided for nation-wide since the curriculum is set to affect all upper secondary schools of Sweden. Making such a large-scale change should not deter anyone if it is made for the better, though it would be wise to test it at a small scale first.

Opinions on Organic chemistry and Biochemistry in *Chemistry 2*

Organic chemistry and Biochemistry are both mentioned by teachers as topics which they wish to reorganize in both courses. Described in the central content for *Chemistry 2*, teachers are obligated to go through reaction mechanisms of organic compounds[10]. Several teachers mentioned the resemblance between *Chemistry 2* and *Biology 2*, here it is clear that the central content benefits teachers with a subject combination of chemistry and biology over teachers with another subject in combinations with chemistry. This difference is highlighted throughout the interviews. There are both benefits and drawbacks with these courses being so similar. One benefit could be that it is easier to create more synergy between subjects which can lead to more applied topics in both subjects, this synergy should increase further if the same teacher teaches both chemistry and biology. A drawback could be that other subjects, like mathematics or physics, lack space in *Chemistry 2*, which according to several teachers is clearly needed.

Possible lack of scientific literacy within Natural Science and Technical programmes

It is possible that the course content in *Natural Science* allows students to become more scientifically literate in comparison to what the content in *Chemistry 1* allows for, as one teacher mentioned. The idea is instead of studying *Natural Science*, like everyone else in upper secondary school, a student studies chemistry, biology and physics as separate subjects if they go to the Natural Science programme or Technical programme. This can be problematic for students at these two programmes as they are only required to study *Chemistry 1* at minimum. Students at the Technical programme are not required to study biology at all but both programmes are required to study the first course of physics, *Physics 1a*[32,33]. Due to these irregularities, it could ironically cause students at the Natural Science and Technical programmes to be less scientifically literate than all other students, which may be worth investigating further.

The level of difficulty of the chemistry courses at upper secondary school could be too low. It is mentioned that if only getting a passing grade in *Chemistry 1*, the student would probably find it difficult to study at a chemistry-heavy programme at university. It might seem acceptable that such students would have a difficult time but achieving only a passing grade in *Chemistry 1* is the minimum requirement in chemistry to study at Chalmers, meaning it is a possibility that those students actually get accepted. It should be pointed out that all other Swedish universities that teach chemistry do require students to have passed *Chemistry 2* also, so the potential issue at hand might only affect Chalmers. Considering how another teacher believes that if students have passed both *Chemistry 1* and *Chemistry 2,* they are likely well-prepared, it might not even be an issue at all for other universities.

Solving misconceptions in chemistry

When teaching concepts in chemistry, it is crucial to teach them in a manner as to not create misconceptions. Sadly, misconceptions seem to be common even at upper secondary school today since, as mentioned in chapter 4.5, university teachers notice problematic misconceptions undergraduates have learnt from upper secondary school. If efforts should be put into counteract misconceptions, they should be introduced at upper secondary school first. This due to only students that study chemistry at upper secondary school will be eligible for higher education in the subject in the first place. The best would of course be that there would not be any problematic misconceptions in chemistry at any level of school, but since it is prominent even at upper secondary school, efforts should be put there, where it will do the most good. A solution to prevent these misconceptions could be to teach chemistry even before upper secondary school, considering how a teacher believes the courses in chemistry at upper secondary school require more time and effort from the students in comparison to other courses of the same size. Granted, students are supposed to study chemistry at lower secondary school, but judging from teachers interviewed, that does not seem to always be the case. Some teachers seem to agree on this, as one suggests teaching basic concepts such as the amount of substance at a younger age, perhaps even before lower secondary school. Such and similar concepts that do not rely on mathematics for understanding could be taught already at a young age.

4.5 Other themes found

During this project themes were found in the interviews that were not present in the survey. In order to answer the question research of this project it was deemed important that these themes were brought up. These additional themes will be presented and discussed in this chapter.

4.5.1 The influence textbooks have on teaching

Seven teachers from upper secondary school shared their opinions on textbooks in chemistry. Five of these teachers mention that the textbooks often govern how the course is taught. One teacher mentions how they used to follow the textbook religiously when they recently started out as a teacher. Another teacher mentions how their usual textbook can be lacking in certain topics, where they add supplements to create good course material. Two teachers think there is too much Organic chemistry and Biochemistry in their *Chemistry 2* textbooks and another teacher believes there is a lot of material in *Chemistry 2* textbooks that is of no use. Another teacher believes that the largest issue when it comes to textbooks is to get students to read them at all, referring to how little students read in school before coming to upper secondary school.

Discussion

Even if it is important for teachers to have the option to be flexible in the choice of textbook, it can be argued that having more standardized textbooks would lead to students having similar knowledge in preparation for higher education. Since it has been shown that textbooks have a lot of influence over what is being taught in the classroom, it is therefore important that textbooks in *Chemistry 1* and *Chemistry 2* focus on topics which are found to be most relevant for higher studies in chemistry. More studies similar to this one could help finding these topics. It is possible to argue that the issue should solve itself, as textbooks that do not reach the standard of teachers will not be used anyhow, but this is under the assumption that the teachers get to decide which textbooks to purchase. That might not be the case for every school for instance due to lack of funds or other organizational reasons.

Furthermore, newly graduated teachers will likely influence their courses due to their own university experience and might also not be aware of all chemistry textbooks available.

4.5.2 The importance of creating interest in chemistry.

A theme that is present at both levels throughout interviews is the goal to create interest in chemistry among students. For teachers at upper secondary school, it can be a way of measuring your own performance as well as improving students and your own experience during class. Several teachers mentioned that the leeway that the central content provides gives more possibilities to create interest for chemistry among students. One teacher mentioned that different schools have different programmes studying chemistry so the flexibility in the central content helps to adapt to different groups of students.

Discussion

We think the reason so many teachers mentioned the importance of creating interest for chemistry, even if it was not explicitly mentioned during every interview, is that if students are interested in the subject, it will improve the learning experience in class. This could in turn motivate students to continue to universities. If we apply this thought process, it is clear why it is so important that upper secondary school focuses on creating an interest in subjects. Further this can be the reason why creating interest does not seem as important at university, due to it being the last steppingstone before the undergraduates start their working life. But considering how just about half of all undergraduates finish their university studies in chemistry within the normal timeframe, it may be beneficial to make university courses more interesting.

We noticed two main ways for teachers to create interest although, this forms a spectrum, and every teacher will not fit perfect to one category. The first category is teachers that want to recreate the circumstances that made them interested in chemistry in the first place. Why change something that works, if you as a teacher feel like the way you learnt was interesting it can be used to create the same experience for others. There are both positives and negatives sides to this way of thinking. The positive side is that the teachers can build on a basic concept, for example: “I want students to experience the joy of doing experiments", which will create a clear goal for the course and further create interest. The downside may be that if the teachers do not communicate the intention or develop their material periodically, the course can feel outdated and repetitive, which can stagnate or even reduce interest.

The second category is teachers that try to adapt to the progression of students to the possible extent, meaning that focus is on what the students are interested in and applying the course material to that interest. This is something that can be used in every kind of class but is often more prevalent in classes with extremely low interest to begin with. In this category, we think that the adaptability that the central content provides is really important. The idea here is to make the course relevant for the students, to show them the need for the material in the course. The positives are that this way of teaching can be applied to every student and they should understand the course in a broader context, which should create interest among the students. The downside with this method is that if you adapt too much to the students and how things are applied, the course can feel overwhelming and prioritize topics which are not beneficial for higher studies in chemistry.

4.5.3 Disparities within groups of students

Several teachers at both upper secondary school and university level point out how they have not seen any trend of better or worse knowledge levels of students/undergraduates over time. Instead, most teachers notice large knowledge differences between students within the same class. At upper secondary school, the student’s previous chemistry knowledge differs much from each other. One teacher gives an example of students' prior chemistry lessons before upper secondary school, which ranged from one week of lessons up to a whole semester. Three other teachers also mention how the variation in prior knowledge is due to their experiences at Swedish lower secondary school (the three years of school prior to upper secondary school) and how it often depends on what teacher they had.

On a similar note, another teacher also talks about how students may choose their programme for wildly different reasons, which may be a factor for varying interest in the subject.

A similar trend is found at university level, where several teachers mention that the knowledge of undergraduates is much dependent on what upper secondary school and programme they went to. They also mention that the knowledge that undergraduates possess varies a lot within their university class, both between those who have read only *Chemistry 1* and those that have read both courses in chemistry. One teacher mentions that there can be a striking difference in prior knowledge of new undergraduates, depending on how many students applied for the university programme, as only the students with the highest grades amongst those who applied get accepted.

Discussion

This variation amongst students seems to permeate the whole school system. Both upper secondary school and university feel like they have to start from zero to not leave some students behind. Teaching a group of students with widely varying prior knowledge, experience and goals with their education would make it difficult to maintain an appropriate level of teaching and still stimulate the whole class. Such diversity within the same class does not seem to do teachers any favours when it comes to building or maintaining interest in the subject or a proper pace of teaching.

It is interesting that teachers at university notice a trend that knowledge between undergraduates in the same class differ much. It would suggest that students receive differing education even though they have read the same courses in chemistry. Both students may pass their *Chemistry 1* course but have earned it by knowing different topics, whereas some topics are more and less useful for higher education. This can in turn cause two newly accepted undergraduates at university, entering with the same grades, yet one being more prepared due to having more relevant prior knowledge in chemistry compared to their peer. This is likely due to how the central content of the syllabi in upper secondary school can be interpreted and prioritized differently and thereby graded differently by upper secondary school teachers. The connection between how teachers prioritize topics and grade their students would be interesting to investigate further in a future study. In a similar fashion, comparing grades of students in chemistry and their actual knowledge would allow for a more quantitative study.

4.5.4 Increased collaboration between upper secondary school and university

Many teachers at both levels talked in their interviews about how the collaboration between upper secondary school and university is almost non-existent. Many university teachers mention how they are unaware of what is being taught at upper secondary school, with some exceptions. The exceptions being university teachers who hold introductory courses, which has been designed to start off where upper secondary school left off, as well as one teacher being a local upper secondary school's programme counsel. Many teachers at upper secondary school are also unaware of what is being taught in chemistry at universities besides their own experiences. One exception being when a newly graduated teacher is employed and shares their more recent university experiences. One teacher at upper secondary school also talks about how they wish there were more cooperation between the two levels.

Discussion

The only university teachers who were informed on what students are taught at upper secondary school were those who are or had been responsible for the chemistry introductory courses, their reason likely being because they found it necessary to develop their introductory courses in the first place. It should be noted that a handful of university teachers are involved in the introductory courses but only a few who are updated on what is being taught in chemistry at upper secondary school. Granted, it is easy to learn what subjects are being taught at upper secondary school since every subject has its central content decided for nation-wide and can be found by searching the Swedish
National Agency for Education's website. Even if easy access is beneficial, upper secondary school teachers may still interpret the central content and decide what they actually teach in their own classroom. It is important to understand that this could lead to university teachers making incorrect assumptions of the knowledge that students possess.

Many upper secondary school teachers seem to plan their courses in chemistry based on their own experiences from their former university studies. As universities develop the content of their courses over time, the experience of the teacher risks becoming outdated with time. The students who plan to study chemistry further may or may not study at the same university or programme as the teacher has, meaning their future chemistry education may be different from what the teacher has learnt. This could lead to students being less prepared for the forms of higher education available now.

Therefore, it would be beneficial that collaboration between upper secondary schools and universities was given more organised form. Upper secondary school teachers will more easily find out what topics are important for their students to know in preparation for higher studies. University teachers would regain some influence over what is being taught at upper secondary school and also be able to adjust their introductory courses to potentially ease the transition of students into higher studies. Depending on what kind of collaboration takes place, it could also create an opportunity for students to be introduced to the concept and culture of universities, which could in turn generate interest in students to pursue higher education.

4.5.5 The misconception of models amongst students.

An issue brought up by several teachers at the universities is the way students use and comprehend models in chemistry. Undergraduates are described to have trouble understanding how and why models are used in chemistry within different contexts. One university teacher says that undergraduates have difficulty accepting that models do not depict reality as it is and in similar fashion find it difficult to accept that humanity does not have exact and complete knowledge of how everything works. Models that students and undergraduates are most often introduced to are models explaining chemical bonding, where Bohr’s model of the atom is commonly used in upper secondary school. One teacher at university level explains how there is a risk in teaching Bohr’s model and using it as a basis for further chemistry teachings, since it cannot be applied at university level because of its limitations. The same teacher explains how it is better to teach chemical bonding from a logical perspective from the very beginning. Only one teacher at upper secondary school mentioned Bohr’s model of the atom, this opinion was that if students at upper secondary school only learns Bohr’s model of the atom and no other, they may feel lied to once they start learning chemistry at university. Another teacher from upper secondary school did however mention metaphors and how they can be harmful for student’s understanding of the subject, giving an example of explaining chemical bonding with anthropomorphic atoms that “like each other”.

Concerning the two teachers thinking there is too much Organic chemistry and Biochemistry in their Chemistry 2 textbooks, they may be biased due to prioritizing Organic chemistry and Biochemistry less or might prioritize Organic chemistry and Biochemistry less due to their opinion on their textbooks containing too much of those topics. It could also be that the select books do in fact contain too much Organic chemistry and Biochemistry for what it is worth. To decide whether or not textbooks contain too much Organic chemistry and Biochemistry, its use for the students could be explored. The usefulness of these topics in preparing students for university should determine their importance. If the topics are not important for university preparation, they ought to be of help in developing a skill, help students in their everyday life or learn it for the sake of it being considered common knowledge for the topics to be relevant at all. Since there are topics other than Organic chemistry and Biochemistry, it becomes a balancing act of which topics are more useful in preparing for university studies.

Discussion

It should be mentioned that we did not experience a difference in opinion about the use of models between upper secondary school and university. The reason this misconception of models is so prevalent could stem from chemical bonding being a large part of the introductory course at university, meaning it is the first case of misinformation the university teachers see among undergraduates. Further we think that this misconception is a by-product of how the school system tests students. If students get the feeling that every answer in school is either right or wrong, it leaves little to no room for discussion and arguments surrounding the grey areas. The way students use models is not as a help to understand a phenomenon but rather as an exact explanation of a phenomenon. This could also be the reason why students have a hard time accepting that two different models can be used to explain the same phenomenon. It is important for both upper secondary school and university to encourage the discussion of how and why we use models.

It is important that upper secondary school and university reach consensus on how they teach certain topics to create a clearer end goal with chemistry as a subject. Even if all topics in chemistry cannot be applied to all students simultaneously, we think that how students view and apply models is one of the more important misconceptions to counteract. Even to the extent that it could be a bigger part of education as a whole, not only in chemistry but in physics and biology too.

4.6 Overall discussion

Here follows a discussion to answer our two research questions based on results and discussion from chapter 4.

4.6.1. Identified Knowledge gaps

There are several factors that affect the knowledge gaps amongst students between upper secondary school and university. By analysing our results and discussion, we elected to focus on three main categories that contribute to the knowledge gaps.

Knowledge gap #1: Upper secondary school teachers rarely teach chemical bonding using atomic orbitals

One knowledge gap that became apparent between upper secondary schools and universities was how students had different knowledge of models regarding chemical bonding. It was brought up by several university teachers how new undergraduates rarely have knowledge of models relevant to chemistry taught at university, specifically orbitals and hybridization. It became apparent when only one upper secondary school teacher brought up this issue, as all other teachers seemed to use only Bohr's atom model to explain chemical bonding and not atomic orbitals. The issue of lacking orbital-based teaching was confirmed by several teachers at university, who report how undergraduates often have only learnt Bohr's atom model, which is of little use when understanding chemical bonding. It could be argued that Bohr's atom model is easier to learn since it is rather simple and therefore aids students' understanding of chemical bonding. This would sadly make students base their understanding of chemical bonding on a model which has several shortcomings. Even if most students will likely not study chemistry at university, having learnt the more modern and useful model of atomic orbitals would benefit them more than learning a nearly obsolete model, which Bohr's atom model is in our view.

We see little to no reason why atomic orbitals should not be key in explaining chemical bonding already at upper secondary school. It could be argued that Bohr's atom model should be retired from Swedish schools entirely. However, we believe it could still be valuable to mention Bohr's atom model for the sake of showing how old models are replaced as new models are developed. In a sense, Bohr's atom model along with other outdated models of the atom could be used as a springboard into making students more amenable to learning atomic orbitals and how they can be used to explain chemical bonding.

Knowledge gap #2: Differences in education between different upper secondary schools

It was brought up by several university teachers that there is a difference in knowledge levels of chemistry between undergraduates within the same class. Since students carry differing prior knowledge, one student ought to be more prepared for further chemistry studies than the other, which is problematic as it can limit how well students advance in the subject. These differences are due to the students' prior knowledge from their earlier upper secondary schools. We find that the teachers believe that the reason for such variation of prior knowledge is due to students coming from different schools that teach *Chemistry 1* and *Chemistry 2* differently.

To avoid having large unwanted variations in knowledge caused by going to different schools, we think that it would be beneficial if the central content specified what specific knowledge is required to pass chemistry throughout all of compulsory school and upper secondary school. Such a change should bring more clarity to what should be taught rather than increase the workload in the course. This would ease the transition between levels of school for both students and teachers, where teachers throughout the school system would not have to start from scratch to make sure all students can benefit from their teaching. One could argue that this would lower the flexibility of the courses in chemistry, which it would to some extent. However, specifying more precisely what knowledge a student must have before continuing to the next stage will guarantee that all students have at least some knowledge which can be built upon at the next stage, resulting in a group of students with more equal education than what is produced today.

It is important to remember that the curriculum of upper secondary school is supposed to be timeless so the subject can develop over time without change to the central content. If the central content were to be changed as we have suggested, it would compromise the timelessness aspect of the curriculum. A timeless structure has its benefits, and we believe a compromise could be made. Instead of changing the central content a national chemistry exam could be created, made obligatory and would therefore carry more weight in the grading process at upper secondary school. This would let teachers keep their current flexibility in the courses while still setting clearer knowledge requirements and allowing the Swedish National Agency of Education to influence what knowledge is considered valuable to teach and learn. This should in turn create a more equal education across the nation and should minimize this knowledge gap.

Knowledge gap #3: How students use and understand mathematics in the context of chemistry

The third knowledge gap is regarding the ability of students to apply mathematics to chemistry. This is something almost every teacher in our study talked about at some point of their interview. Some were satisfied with the students' mathematical skill and some were not. We do not think mathematical skill is a huge contributor to the current knowledge gap between upper secondary school and university, but we think that it could become one if mathematical knowledge in Sweden would decline. There could even be reason to add more mathematics to *Chemistry 2* to further increase students' ability to apply mathematics to chemistry. This could ease the transition from *Chemistry 2* to the more mathematical focused chemistry course at university.

4.6.2 Identified influences of prioritization and how does it affect knowledge gaps.

Over the course of this project, it has become apparent that most teachers at both levels prioritize the various topic of chemistry similarly to each other. It is clear to us that the prioritization made by upper secondary school teachers has a large impact on what students learn in preparation for higher studies. If upper secondary school teachers and university teachers would prioritize topics in chemistry even more similarly, the knowledge gaps will decrease. It is important to mention that universities are in some way forced to adapt to the level of knowledge amongst students they recruit. It is therefore important that prioritization is similar between the two levels.

The prioritization overall is similar but there were some differences that depend on three main factors. By analysing our results and discussion we have found the following three factors having an effect on the teachers' prioritization of topics and how it could affect the knowledge gaps of students between upper secondary school and universities.

The first factor is the different views regarding how to create interest amongst students. An interest in chemistry is something teachers at both levels wanted to create amongst their students, but there seems to be a difference in the way teachers think students reach this. Some teachers mention that if students understand basic chemistry with a focus on Stoichiometry, the interest will grow when they get the chance to apply it to real life. Other teachers mentioned that the interest of students will grow if they can see the use for it in their everyday life, the focus will instead be on Chemistry's character and work procedure. We do not think any of these two approaches are better than the other, but it is an important factor for understanding why there could be a difference in prioritization of topics in chemistry amongst teachers.

The second factor that we noticed was the impact that the chemistry textbook has on the teachers' prioritization. These observed effects could cause two like-minded teachers to teach differently. If teachers are introduced to a textbook and use it as a reference for the course, it will probably influence their prioritizing of different parts in the central content.

The third and last factor is the variety of the students each teacher faces. Chemistry at upper secondary school is presented to a broader audience and only a small group of students will likely continue their studies in chemistry at universities. The central content therefore needs to be flexible to handle a large variance of students.

We think these factors are important to be aware of and that they can influence the prioritization of topics within the central content. If upper secondary school teachers are not on the same page regarding the importance of each part of the central content it would create inequality among students across the country. This will increase the knowledge gaps between upper secondary school and university.

The final question one might ask is which level should adapt to whom, upper secondary school or university? The Education Act[4] is clear when it defines the purpose of Swedish upper secondary school; the education is to be the foundation for the recruitment to higher education. The purpose of the education given at universities is defined in The Higher Education Act[17], which is to benefit our society. However, universities are also obligated to build their undergraduate education upon the knowledge students have received from upper secondary school. Even if universities are obligated to adapt to what undergraduates were taught at upper secondary school, only upper secondary schools have the explicit purpose to form their education to prepare students for higher studies. It should therefore be of interest for teachers at upper secondary schools that teach *Chemistry 1* and *Chemistry 2* to seek advice from university teachers when interpreting and prioritizing topics in chemistry, because the university teachers probably have a better understanding of what students need in preparation for higher education. It is therefore important for upper secondary school teachers to have their sights on the same goal in *Chemistry 1* and *Chemistry 2*. We think that it is beneficial that a continuous pedagogical conversation between university teachers and upper secondary school teachers is maintained. Discussing interpretations about the curriculum, how knowledge of chemistry is applied and about students' difficulties in chemistry should create a clear common goal in the subject of chemistry for teachers to strive for. Sadly, it is unlikely that upper secondary school teachers and university teachers have time for such a pedagogical exchange. Since it should be considered teacher training, teachers at both levels should be given time for this kind of pedagogical exchange that would be valuable for both levels.

4.6.3 Comparing previous research to our findings

As presented in subchapter 2.1, a master thesis[6] found that students that believed they had adequate prior knowledge for higher studies whilst their teachers did not. This gave our project more reason to seek out teachers' opinions on student knowledge rather than the students themselves. The other presented master thesis[7] found that undergraduates often noticed a difference in how chemical bonding is taught between upper secondary school and university level, something our study also has found. More specifically that Bohr's atom model is more prevalent at upper secondary school whilst atomic orbitals are more prevalent at university level. The American study[8] mentioned that if students have knowledge in stoichiometry and mathematics, they are more likely to perform well at university level chemistry, which is further supported by our findings indirectly through how teachers at both levels prioritize these topics. In the Swedish study[9] that compared teachers' beliefs in teaching to what students want to learn in science, our findings also indicate that teachers base their teaching beliefs, and therefore their prioritization of topics, on earlier experiences. Our project further contributes with three identified knowledge gaps in chemistry, three factors which affect prioritization of topics in chemistry, three suggestions of future research (listed in chapter 5) as well as a handful of unexpected themes outside of our project scope.

4.6.4 International relevance

Under the assumption that the universities Chalmers and Gothenburg university conduct their education and research at an international standard, our findings regarding knowledge gaps and prioritizations could also be applied internationally. Since different countries can have widely different educational systems, it can be difficult to compare what chemistry knowledge students have by just referring to the name of a topic. The difficulty to compare topics internationally comes from the possibility of learning a topic at different depths and detail. Therefore, if a study preparation programme aims to prepare their students even better for higher education in chemistry, they could find our themes and suggestions valuable. For example, if chemical bonding is taught without the knowledge of atomic orbitals at study-preparation programmes, those students risk lacking some understanding of chemical bonding which is expected at university level. In the case of study-preparation programmes found producing graduates with detrimentally varying knowledge in chemistry, a national obligatory test could be of interest to ensure that valuable knowledge is acquired, if our arguments are applicable in said country. Also, if study-preparation programmes wish to keep their teachers updated on modern insights in their subject and how to teach it, collaboration between the study-preparation programme and universities should be made as to encourage pedagogical conversation and development.

5. Concluding remarks

This project attempted to answer our research question to the extent possible. Teachers can more easily point out students’ knowledge gaps when they can project it on students' struggles in upper secondary school or university. The complexity mainly stems from the second research question, where the focus is set on how teachers’ perspectives of their own prioritization relate to the knowledge gaps. There are several factors that interact with each other and it is too complicated for this project to draw any reliable conclusions on how prioritization directly affects the knowledge gaps.

Instead, our goal was to give context to what affects teacher’s prioritization and interpretation of topics and, to an extent, show teachers at both levels how it could affect the previously mentioned knowledge gaps.

Future research

We hope that this project will spark further discussion and research surrounding teacher’s prioritization of topics in chemistry. There are a lot of subjects mentioned in our report that could be a project on its own. We want to highlight three potential project questions that would be interesting to research at both upper secondary school and university.

- How does students’ ability to apply mathematics to chemistry affect their overall knowledge about chemistry? We think if shown with enough arguments behind it could have a large influence on how the school system will develop.
- Which topics in chemistry could be considered basic knowledge for chemistry at upper secondary school? It is important to create a foundation for discussion, as any discussion needs a starting point to base arguments around. This is something a definition of basic chemistry could provide.
- What is the connection between how teachers prioritize topics and how they grade their students? This connection would be interesting to examine to see if the prioritization of topics in chemistry affect what actual knowledge is learnt by students.

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Appendices

Appendix 1.

Kursen kemi 1 omfattar punkterna 1–5 under rubriken Ämnets syfte.

Centralt innehåll

Materia och kemisk bindning

- Modeller och teorier för materiens uppbyggnad och klassificering.
- Kemisk bindning och dess inverkan på till exempel förekomst, egenskaper och användningsområden för organiska och oorganiska ämnen.

Reaktioner och förändringar

- Syrabasreaktioner, inklusive pH-begreppet och buffertverkan.
- Redoxreaktioner, inklusive elektrokemi.
- Fällningsreaktioner.
- Energiomsättningar vid fasomvandlingar och kemiska reaktioner.

Stökiometri

- Tolkning och skrivning av formler för kemiska föreningar och reaktioner.
- Substansmängdsförhållanden, koncentrationer, begränsande reaktanter och utbyten vid kemiska reaktioner.

Analytisk kemi

- Kvalitativa och kvantitativa metoder för kemisk analys, till exempel kromatografi och titrering.

Kemins karaktär och arbetssätt

- Vad som kännetecknar en naturvetenskaplig frågeställning.
- Modeller och teorier som förenklingar av verkligheten. Hur modeller och teorier kan förändras över tid.
- Hur problem och frågor avgränsas och studeras med hjälp av kemiska resonemang.
- Det experimentella arbetets betydelse för att testa, omvärdera och revidera hypoteser, teorier och modeller.
- Planering och genomförande av experiment samt formulering och prövning av hypoteser i samband med dessa.
- Utvärdering av resultat och slutsatser genom analys av metodval, arbetsprocess och felkällor.

- Ställningstagande i samhällsfrågor utifrån kemiska modeller, till exempel frågor om hållbar utveckling.

Kursen kemi 2 omfattar punkterna 1–5 under rubriken Ämnets syfte.

- Reaktionshastighet, till exempel katalysatorers och koncentrationers inverkan på hur fort kemiska reaktioner sker.
- Faktorer som påverkar jämviktslägen och jämviktskonstanter.
- Beräkningar på och resonemang om jämviktssystem i olika miljöer, till exempel jämviktssystem i världshaven, i människokroppen och inom industriella processer.

Organisk kemi

- Olika organiska ämnesklasser, deras egenskaper, struktur och reaktivitet.
- Reaktionsmekanismer, inklusive kvalitativa resonemang om, hur och varför reaktioner sker och om energiomsättningar vid olika slags organiska reaktioner.

Biokemi

- Det genetiska informationsflödet, inklusive huvuddragen i de biokemiska processerna replikation, transkription och translation.
- Huvuddragen i människans ämnesomsättning på molekylär nivå.
- Proteiners struktur och funktion, med speciellt fokus på enzymer.

Analytisk kemi

- Kvalitativa och kvantitativa metoder för kemisk analys, till exempel masspektrometri och spektrofotometri.
- Resonemang om provtagning, detektionsnivå, riktighet och precision samt systematiska och slumpmässiga felkällor.

Kemins karaktär och arbetssätt

- Modeller och teorier som förenklingar av verkligheten. Modellers och teoriers giltighetsområden och hur de kan utvecklas, generaliseras eller ersättas av andra modeller och teorier över tid.
- Avgränsning och studier av problem och frågor med hjälp av kemiska resonemang.
- Det experimentella arbetets betydelse för att testa, omvärdera och revidera hypoteser, teorier och modeller.
- Planering och genomförande av experimentella undersökningar och observationer samt formulering och prövning av hypoteser i samband med dessa.

- Utvärdering av resultat och slutsatser genom analys av metodval, arbetsprocess och felkällor.
- Frågor om etik och hållbar utveckling kopplade till kemins olika arbetssätt och verksamhetsområden.

Appendix 2

Enkät: Gymnasieundervisning.

Hej! Här kommer enkäten som innehåller sex frågor, dessa är för att ge oss ett bredare underlag kring kemiundervisning på gymnasiet. Det är bra om skriver ditt namn längst upp i enkäten så vi kan använda svaren som utgångspunkter i intervjun. Allt som används från enkät och intervju i rapporten kommer anonymiseras. Vi vill igen tacka för att du tar dig tiden att svara på enkäten.

*Obligatorisk

1. Har du någon erfarenhet av att jobba med kemi utanför rollen som lärare? (Do you have any experience of working with chemistry outside the role of a teacher?) *

Ditt svar

---

2. Hur viktig är varje del från det centrala innehållet i Kemi 1 att eleverna har med sig från gymnasiet inför universitetsstudier? (How important is each part from the central content in Chemistry 1 that the students acquire from upper secondary school in preparation for university studies?) *

	1. Oviktigt (Unimportant)	2. Delvis oviktigt (Partly unimportant)	3. Varken oviktigt eller viktigt (Neither unimportant or important)	4. Delvis viktigt (Partly important)	5. Viktigt (Important)
Materia och Kemisk bindning (Matter and chemical bonding)	○	○	○	○	○
Reaktioner och förändring (Reaction and change)	○	○	○	○	○
Stökiometri (Stoichiometry)	○	○	○	○	○
Analytisk Kemi (Analytical chemistry)	○	○	○	○	○
Kemins karaktär och Arbetssätt. (Chemistry's character and work procedures)	○	○	○	○	○

3. Hur viktig är varje del från det centrala innehållet i Kemi 2 att eleverna har med sig från gymnasiet inför universitetsstudier? (How important is each part from the central content in Chemistry 2 that the students acquire from upper secondary school in preparation for university studies?) *

	1. Oviktigt (Unimportant)	2. Delvis oviktigt (Partly unimportant)	3. Varken oviktigt eller viktigt (Neither unimportant or important)	4. Delvis viktigt (Partly important)	5. Viktigt (Important)
Reaktionshastighet och kemiska jämvikt (Reaction speed and chemical equilibrium)	○	○	○	○	○
Organisk kemi (Organic chemistry)	○	○	○	○	○
Biokemi (Biochemistry)	○	○	○	○	○
Analytisk Kemi (Analytical chemistry)	○	○	○	○	○
Kemins karaktär och Arbetssätt. (Chemistry's character and work procedures)	○	○	○	○	○

4. Vad brukar eleverna ha svårt för inom kemi på gymnasiet? (What do students usually find difficult in chemistry at upper secondary school?) *

Ditt svar

5. Tycker du någonting saknas i Kemi 1 eller Kemi 2 inför högre studier? (Do you think something is missing in Chemistry 1 or Chemistry 2 in preparation for higher education?) *

Ditt svar

6. Tycker du att någon eller några delar i kurserna Kemi 1 och Kemi 2 borde omfördelas? (Do you think that any or some parts of Chemistry 1 and Chemistry 2 should be reorganized?) *

Ditt svar

Appendix 3

Enkät: Universitetsundervisning.

Hej! Här kommer enkäten som innehåller fem frågor, dessa är för att ge oss ett bredare underlag kring kemiundervisning på gymnasiet. Det är bra om skriver ditt namn längst upp i enkäten så vi kan använda svaren som utgångspunkter i intervjun. Allt som används från enkät och intervju i rapporten kommer anonymiseras. Vi vill igen tacka för att du tar dig tiden att svara på enkäten.

*Obligatorisk

1a. Vilka kemikurser har du undervisat på universitet? (What courses have you taught at university?) *

Ditt svar

1b. Vilka årskurser har du undervisat på universitet? (Which academic years have you taught at the university?) *

Ditt svar

2. Hur viktig är varje del från det centrala innehållet i Kemi 1 att studenterna har med sig från gymnasiet inför universitetsstudier? (How important is each part of the central content in Chemistry 1 that the undergraduates acquire from upper secondary school in preparation for university studies?) *

	1. Oviktigt (Unimportant)	2. Delvis oviktigt (Partly unimportant)	3. Varken oviktigt eller viktigt (Neither unimportant or important)	4. Delvis viktigt (Partly important)	5. Viktigt (Important)
Materia och kemisk bindning (Matter and chemical bonding)	○	○	○	○	○
Reaktioner och förändring (Reaction and change)	○	○	○	○	○
Stökiomerti (Stoichiometry)	○	○	○	○	○
Analytisk kemi (Analytical chemistry)	○	○	○	○	○
Kemins karaktär och arbetssätt (Chemistry's character and work procedures)	○	○	○	○	○

3. Hur viktig är varje del från det centrala innehållet i Kemi 2 att studenterna har med sig från gymnasiet inför universitetsstudier? (How important is each part of the central content in Chemistry 2 that the undergraduates acquire from upper secondary school in preparation for university studies?) *

	1. Oviktigt (Unimportant)	2. Delvis oviktigt (Partly unimportant)	3. Varken oviktigt eller viktigt (Neither unimportant or important)	4. Delvis viktigt (Partly important)	5. Viktigt (Important)
Reaktionshastighet och kemisk jämvikt (Reaction speed and chemical equilibrium)	○	○	○	○	○
Organisk kemi (Organic chemistry)	○	○	○	○	○
Biokemi (Biochemistry)	○	○	○	○	○
Analytisk kemi (Analytical chemistry)	○	○	○	○	○
Kemins karaktär och arbetssätt (Chemistry's character and work procedures)	○	○	○	○	○

4. Vad brukar studenterna ha svårt för inom kemi på universitetet? (What do undergraduates find difficult in chemistry at university?) *

Ditt svar

5. Vad upplever du att studenterna saknar inom kemi när de börjar på universitet? (What do you feel undergraduates lack in chemistry when they start at the university?) *

Ditt svar

Appendix 4

Frågor för Gymnasiet

Intro

Vad har du för utbildning?

Hur länge har du jobbat som lärare?

Vilka program har du undervisat?

- Vilka kurser inom kemi har du hållit i?

Kurser

Vad tänker du på när du lägger upp en kurs inom kemiämnet? Du kan utgå ifrån din senaste kurs.

- Har sättet du lägger upp kurser förändrats med tiden?

Vilka delar i kurserna tar längre tid att gå igenom än andra?

Känner du att du har koll på vad för kemi som undervisas på högskolan?

- Hur var kemiundervisningen under din egen universitetstid?
- Något viktigt du tog med dig?
- Influerar det din undervisning?

Vad tycker du är viktigt för eleverna att ha med sig från kemin i sitt fortsatta liv?

- Vad tänker du kring gymnasieskolans två olika syften: att förbereda eleverna inför arbetslivet kontra högskolestudier?
- Hur tänker du kring prioritering av dessa?

Centrala innehållet och högskolestudier

Utifrån centrala innehållet i kemi 1 har du valt detta som det viktigaste inför universitetsstudier?

- På vilket sätt är det viktigt?

Vad tycker du är mindre viktigt? Varför valde du att prioritera den lägre?

Utifrån centrala innehållet i kemi 2 har du valt detta som det viktigaste På vilket sätt är det viktigt?

Vad tycker du är mindre viktigt?

- Varför valde du att prioritera den lägre?

Är det viktigt att lärare prioriterar liknande saker?

Förändringar i skolämnet

Känner du att du hinner ge eleverna den kunskap som behövs för att börja läsa kemi på universitetet?

Vad skulle du vilja förändra inom gymnasieämnet kemi?

- På vilket sätt är Kemi 2 relevant inför högre kemistudier?

Tycker du någonting saknas i Kemi 1 eller Kemi 2 inför högre studier?

- Ger kursplanerna det som behövs för att förbereda elever inför högre studier i kemi?

Tycker du att någon eller några delar i kurserna Kemi 1 och Kemi 2 borde omfördelas?

Elevernas förkunskaper från högstadiet

Har du över tid märkt någon förändring av elevernas förkunskaper när de börjar på gymnasiet?

- När märkte du av förändringarna?

Har du något att tillägga? Något du har känt att du inte fått säga?

Appendix 5

Frågor för Universitetet

Intro

Vilken utbildning har du?

Hur länge har du jobbat som lärare?

Har du jobbat med kemi någon annanstans än på universitetet?

- Har det påverkat hur du undervisar kemi?

Vilka kurser inom kemi har du hållit/deltagit i?

- Vilka program har du undervisat för då?
- I vilken årskurs ges kursen?

Har du/ni några externa samarbeten med andra lärare? (På gymnasiet, universitet eller basår?)

Kurser

Vad brukar du ha i åtanke kring upplägg av dina kemikurser?

- Tar du hänsyn till studenternas förkunskaper vid upplägg av kurserna?

Hur bestäms förkunskapskrav och kursmål i dina kemikurser?

Hur har dina kurser förändrats med tiden?
Hur brukar du utveckla kurserna? Gör det i samråd med andra?

Har du nytta av din egen forskning i din undervisning?

- På vilket sätt då?

Vad är skillnaden mellan kemiundervisning på gymnasiet och universitetet enligt dig?

Centrala innehållet

Känner du till det centrala innehållet i kemi från gymnasieskolan innan du såg de i enkäten?

Utifrån centrala innehållet i kemi 1 har du valt **XXX** som det viktigaste inför universitetsstudier?

- På vilket sätt är det viktigt?
- Om du var tvungen att välja en?

Vad tycker du är mindre viktigt?

- Varför valde du att prioritera den lägre?

Utifrån centrala innehållet i kemi 2 har du valt **XXX** som det viktigaste • På vilket sätt är det viktigt?

Vad tycker du är mindre viktigt?

- Varför valde du att prioritera den lägre?

Studenternas kunskaper

Vad brukar studenterna ha svårt för i kemin på universitet?

- Vad kan studenterna väl innan de börjar universitetet?
- Vad brukar studenterna ha lätt för att lära sig i dina kurser?

Vad hade du hoppats studenterna kunde mer om när de börjar på kemiprogrammet?

Har du över tid märkt någon förändring av studenternas förkunskaper när de börjar på universitetet?

- När märkte du av förändringarna?

Har du något att tillägga? Något du har känt att du inte fått säga?