CHALMERS
UNIVERSITY OF TECHNOLOGY

Out-Of-School Laboratory Activities

An Observational Study of how Visits to a University Laboratory on a Regular Basis affects Secondary School Students' Interest in Chemistry and Further Education in Science.

Master's thesis in Learning and Leadership

SARA JUUL

Department of Communication and Learning in Science
CHALMERS UNIVERSITY OF TECHNOLOGY

Gothenburg, Sweden 2019

MASTER'S THESIS 2019: CLSX35

Out-of-school laboratory activities

An observational study of how visits to a university laboratory on a regular basis affects secondary school students' interest in chemistry and further education in science.

SARA JUUL

CHALMERS
UNIVERSITY OF TECHNOLOGY

Department of Communication and Learning in Science
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2019

Out-of-school laboratory activities.
An observational study of how visits to a university laboratory on a regular basis affects secondary school students' interest in chemistry and further education in science.

SARA JUUL

Supervisor: Helena Olofsdotter Stensöta
University of Gothenburg, Department of Political Science
Examiner: Samuel Bengmark
Chalmers University of Technology, Department of Mathematical Sciences

Master's Thesis 2019: CLSX35
Department of Communication and Learning in Science
Chalmers University of Technology
SE-412 96 Gothenburg
Telephone +46 31 772 1000

Gothenburg, Sweden 2019

Out-of-school laboratory activities.
An observational study of how visits to a university laboratory on a regular basis affects secondary school students' interest in chemistry and further education in science.

SARA JUUL

Department of Communication and Learning in Science
Chalmers University of Technology

Abstract

This master's thesis project comprises a study with the aim to investigate how visits to a university laboratory at a regular basis can affect secondary school student's interest in chemistry and further education in science. The project also aimed to investigate the differences between the laboratory activities at Chalmers and a secondary school laboratory. The research questions were investigated by an observational study of a class performing lab experiments at Chalmers on a regular basis. A control group for the study was chosen from a school with similar admission points and students of similar socioeconomic backgrounds. The participating students' interest in chemistry and further education in science were measured by a survey before and after the observational study. The differences between the laboratory activities at Chalmers and the control school were investigated by direct observations.

The results showed no significant increase of students' interest in chemistry and further education in science due to visits to Chalmers after a statistical difference-in-difference analysis. The direct observations showed some differences between the laboratory activities, such as that the laboratory at Chalmers appeared less suitable for the experiments being performed. Further differences include the observed teachers' way of acting in the laboratory. Taken together, the most likely conclusion that can be drawn is that the visits to a university laboratory on a regular basis to some extent promotes students' interest in chemistry and further education in science, however, that this effect was neutralized by how the teacher conducted the experiments in the control group. Further research is required to verify this conclusion. Some areas of improvement during the observed laboratory activities at Chalmers were found and implementation of these could increase the promotion of students' interest due to the visits.

Keywords: Secondary School, Chemistry, Science Education, Student Labs, Out-of-school Learning, Interest, Further Education

Acknowledgements

This project would not have been possible without the participation of teachers and students from the two participating schools in Gothenburg. Teachers and schools participating will not be mentioned by name, but my sincerest thanks are sent to them for making this thesis come together.

I would also like to thank my supervisor Helena Olofsdotter Stensöta, for the help and support during this project. Further, I would like to send special thanks to Mattias Agerberg, University of Gothenburg, for the support with the statistical analysis of the survey answers.

Sara Juul
Gothenburg, May 2019

Table of contents

1 Introduction.. 1

1.1 Glossary *1*

1.2 Background *2*

1.3 Project description *2*

1.3.1 Aim.. 3

1.3.2 Research questions 3

1.3.3 Strengths and limitations 3

2 Previous research 5

2.1 Students' interest in science and further education *5*

2.1.1 The importance of out-of-school learning 6

2.1.2 Role models in science 8

2.2 Lab experiments as a learning activity *8*

3 Methodology 11

3.1 Participants in the studies *11*

3.2 Study 1 .... *11*

3.2.1 Implementation 13

3.2.2 Statistical analysis 14

3.3 Study 2 .... *15*

3.3.1 Implementation 16

4 Results 19

4.1 Study 1 .... *19*

4.1.1 Students' backgrounds 19

4.1.2 Students' interest in chemistry 20

4.1.3 Students' interest in further education 23

4.2 Study 2 .... *24*

4.2.1 Summary 28

5 Concluding discussion 31

5.1 Discussion *31*

5.1.1 Study 1 31

5.1.2 Study 2 33

5.1.3 Further discussion 35

5.2 Conclusions *36*

5.3 Further research *36*

References 39

A Appendixes I

A.1 Student survey .... *I*

A.2 Open survey questions .... *IX*

A.3 Laboratory instructions .... *XV*

1
Introduction

The interest for science and chemistry among secondary school students are decreasing in both Swedish and international contexts (Sjøberg 2010). Hence, there has been plenty of research performed to identify why this is happening and how the interest among students can be increased. This report presents a study on how said interest is affected by visits to a university laboratory on a regular basis. Prior, research has been performed to investigate how singular visits to a university laboratory affects students' interest (Glowinski and Bayrhuber 2011, Itzek-Greulich, Flunger et al. 2015), but no studies on visits during a longer period of time on a regular basis have been performed. Further, if showing positive results, the study might work as a recommendation for schools to set up visits to a university nearby. The questions at issue described in section 1.3.2 will be investigated by an observational study and direct observations in order to find if there is a causal link between visits to a university laboratory at a regular basis and increased interest in chemistry and further education in science.

The introductory chapter aims to provide the reader with a background of the project to motivate the study and research questions. Below is a glossary over translations from Swedish to English to clarify some of the terms used in the report. The chapter also includes the specific research questions, aim, strengths and limitations of the study to provide a framework for the project.

1.1 Glossary

Since this report is written in English on a study performed in Sweden there are no direct translations of words describing the Swedish school system. Below is a glossary explaining what the English words used in the report refer to in the Swedish school system.

Class ………………………...……………… Klass
First grade …………………………………Första året på gymnasiet
Middle school …………………………….. Grundskola
Science program …………………………. Naturvetenskapsprogrammet
Secondary school ………………………… Gymnasiet
Secondary science subjects ………………. Naturvetenskapliga ämnen på gymnasienivå
Second grade …………………………….. Andra året på gymnasiet
Teacher student ………………………….. Lärarstudent (VFU-student)
Upper secondary school …………………. Gymnasiet

1.2 Background

Trends show a decrease of interest in science subjects, including chemistry, among students in both Sweden and other countries (Sjøberg 2010, Broman, Ekborg et al. 2011). This is a problem as it is argued that when fewer students find interest in chemistry and further education in science, it might affect the industry with a lack of work force (Swedish Public Employment Service 2019). The chemical industry is a big part of Sweden's economy. It provides for roughly 12 percent of the country's export, making it the third largest export category (Statistics Sweden 2019). Further, it is discussed by Sjøberg (2010) among others that science is important to learn for all students, not only students striving for a career in science. One of the reasons mentioned by Sjøberg (2010) for why all students would benefit from learning science is that when a large proportion of people have some scientific knowledge it promotes democracy and culture. In a study by the National Agency for Higher Education (2003) it is stated that the number of registered students at chemistry oriented university programs has decreased considerably. The number of applicants to chemical higher educations in 2002 were about 25 percent of the number of applicants in the middle of 1990s. Further, by observing statistics from the Swedish Higher Education Authority (2019) from the last ten years it can be seen that the amount of registered students at chemical programs has barely changed from 2008 until 2018. As the National Agency for Higher Education (2003) stated, it is not believable that the need for graduate chemists in the future will be filled in Sweden.

Why is students' interest in science and chemistry decreasing? This problem has been examined previously. A first explanation by Sjøberg (2010) may be that secondary school science is regarded to be difficult subjects. There is also a general perception of science subjects in school requiring much dedication. A second explanation could be that students don't find science to be meaningful on an individual level (Sjøberg 2010, Broman, Ekborg et al. 2011). There are also studies on what can be done to encourage interest and further education in science among students. Teaching secondary science subjects is strongly associated with performing lab experiments in school laboratories and if performed in a good way, they are considered to improve students' interest and knowledge (Fisher, Harrison et al. 1998, Millar 2004). In previous research the influence on students' interest in science has for example been examined as a result of different variations in the teaching of the subject. Field trips and similar activities have been seen to improve students' interest in science in several studies (Braund and Reiss 2006, Luehmann 2009, Glowinski and Bayrhuber 2011, Itzek-Greulich, Flunger et al. 2014). The impact on students' interest in science as a result of lab experiment activities at a university laboratory on a regular basis has not been examined to the same extent. The impact on students' interest is interesting to investigate further since letting students participate in visits to a university on a regular basis may increase their interest in a long-term perspective. As concluded by Glowinski and Bayrhuber (2011), it is more likely that students develop interest in science if they participate in science-related projects that stretch over a longer period of time. Further studies by Dabney, Tai et al. (2012) among others, also concludes the same: if participating during a longer period of time, students' developed interest in science is more likely to remain. Studies as these motivates the importance to investigate how students are affected by visits to a university laboratory on a regular basis.

1.3 Project description

There is a need to increase knowledge about what affects students' interest in chemistry and further education in science. This study investigates in particular the importance of lab experiments for the interest in science and a science related career. The focus of this project is to investigate if regular visits to a university increases students' attitudes towards chemistry and further education. The project is divided into two separate but related studies. Study 1 will investigate students' interest in chemistry and further education in science and Study 2 will investigate the differences that can be observed between the two investigated lab situations.

1.3.1 Aim

The project aim is to investigate if there is a causal link between performing lab experiments at a university and increasing interest in chemistry and further education in science among secondary school students. This will be examined in Study 1 by an observational study of students from two schools in Gothenburg. Students from one of the schools participating are performing lab experiments at Chalmers University of Technology on a regular basis. The students from the other participating school perform lab experiments in a laboratory located at the school.

Further, direct observations and interviews will be performed to investigate the difference between laboratory activities at Chalmers and a secondary school in Study 2. The study will investigate how the lab situation at Chalmers differs from a lab situation at a laboratory located in an upper secondary school.

1.3.2 Research questions

The project investigates the three following research questions:

1. Do regular visits to a university laboratory generally affect secondary school students' attitude towards chemistry compared to students performing lab experiments in their regular school laboratory?

    a. Does students' interest in chemistry increase?

    b. Does students' interest in further education in science increase?

2. How does the lab situation performed at Chalmers differ to the lab situation at a laboratory located in an upper secondary school in regard of the design of lab experiments and the teacher's acting?

3. Can the results from research question 2 help to make explain the results from question 1, and if so how?

Research question 1 will be answered by the results from Study 1 and research question 2 will be answered by Study 2. The results from both studies will then be combined to answer research question 3.

1.3.3 Strengths and limitations

The strengths of the project lie within the design for Study 1. Observational studies have been proved a reliable method to determine causality. By introducing Study 2 in the project, the weaknesses of the observational study discussed in section 3.2 will be accounted for to control if the teaching at the different schools affects students' interest. The strengths and weaknesses of the chosen methodology of the project is discussed further in section 3.2 and 3.3. Because of the strong design of the studies, conclusions drawn from the project can be used as guidelines to secondary schools debating whether or not to invest time in visits at a university laboratory.

Study 1 will investigate interest in chemistry and further education in science at students in the first year in upper secondary school at schools in Gothenburg. The study will not consider individual changes of interest for the students, but regard students in the class as a group. Further, the study will neither consider schools with different socioeconomic background than the two chosen schools. If students with different backgrounds are affected in another way by performing lab experiments at a university will not be investigated. Concepts presented in chapter 2 in the report will be considered the only factors that may affect students' interest in chemistry and further education in science. The study will be performed in a time period of six months. Any changes in interest by the students as a result of regular visits to Chalmers during a longer time period will not be investigated.

In Study 2, the teachers responsible for the students participating in Study 1 will be observed while teaching classes in second grade at the same schools. Observations will only be conducted in two schools, the school at the Chalmers laboratory and the control school in a school laboratory, to identify possible differences. Due to time limitations, two observational occasions will be performed in each laboratory.

2

Previous research

It is well-established that the interest of science and further education in science is decreasing among students (Broman, Ekborg et al. 2011). Hence, there has been plenty of research performed to identify why this is happening and how the interest among students can be increased. This chapter introduces the most relevant research in the area and can be read as a literature study of well-established papers on the subject. The aim of the chapter is to give the reader an overview on previous research in related research fields and enough background to follow the reasoning throughout the report.

2.1 Students' interest in science and further education

The interest in science among secondary school students is decreasing according to a wide range of studies (Sjøberg 2010, Broman, Ekborg et al. 2011). An early study by Gunnarson (2009) focusing on Swedish upper secondary school students' interest in and attitudes towards scientific research, showed low interests in chemistry, physics and biology. When asking students what would increase their interest, answers found pointed at the importance of making connections between the research performed today and its applications and benefits in the society were requested. Further, students wanted to perform simple research early on, perhaps in the form of field trips (Gunnarson 2009). A general opinion of the students was that the science subjects in school have to become more inspiring. Gunnarson (2009) also asked students whether they could imagine themselves working as a researcher in the future. Roughly 33 percent of the students said yes, but on the other hand, 50 percent of the students answered that they did not know what the job of a researcher means. Students that were positive towards performing research were mostly motivated by helping others, for example by developing new medicines. Dabney, Tai et al. (2012) concluded that students that had been interested in science or mathematics since middle school had 1.8 respectively 1.9 times higher odds to be interested in a science related career. The socioeconomic background of students is also of relevance to the interest in a career in science. Dabney, Tai et al. (2012) saw that students with higher socioeconomic status were generally more likely to be interested in a career in science.

In a study by the Swedish Council for Higher Education (2017) it was presented that among Swedish citizens, people are more likely to take part of further education at university if both parents have a university degree. The study did not examine different major fields of study, for example science, but investigated university education in general. Individuals with two parents holding a university degree were favored through the school system. This was for example implemented by earlier information of higher education, higher enrollment in secondary schools focused on further education and by advice by parents promoting university studies. The Swedish Council for Higher Education (2017) also presents statistics that individuals with highly educated parents are more aware of the status of higher education. Those individuals are also more likely to relocate longer distances to a university. The same trends could be seen, but to a lower degree, if only one of the parents had a university degree. The opposite trends were shown for individuals from families with no academic degrees.

In this study, students with quite low socioeconomic status will be participating. Thus, the increase of students' interest in science and further education due to family and background conditions can be expected to be low. Previous research of the causal factors that will be investigated in the study is presented below. The main factor that will be investigated is the visits to Chalmers on a regular basis. Further, factors as the role model mechanism and the teachers' way of teaching will be accounted for and discussed.

2.1.1 The importance of out-of-school learning

The term *out-of-school learning* is a wide concept including everything from unstructured learning happening in students' homes to structured field trips to science centers or museums. In conclusion, out-of-school learning is all learning that takes place in a different setting than the regular classroom. Several studies have presented results that show the importance of out-of-school learning experiences for increased student learning and/or motivation in science (DeWitt and Osborne 2007, DeWitt and Storksdieck 2008, Glowinski and Bayrhuber 2011, Dabney, Tai et al. 2012, Itzek-Greulich, Flunger et al. 2014). Braund and Reiss (2006) describe the contribution of out-of-school situations as possibilities of improved development of concepts for students. Extended and authentic practical work, access to rare material and big science and stimulating for further learning and collaborative work can also be reached in an out-of-school setting. All of these can be hard to reach if the teaching only takes place in school, promoting out-of-school activities as a part of science education (Braund and Reiss 2006).

When discussing field trips as out-of-school learning activities many researchers focus on museum visits and how these can be performed to maximize students' learning and interest (Braund and Reiss 2006, DeWitt and Osborne 2007, DeWitt and Storksdieck 2008). A museum visit cannot be directly comparable to the type of out-of-school activities regarded in this report. Some parallels may be drawn however, which motivates research in previous studies on how to design museum visits to promote students' learning and interest in science. DeWitt and Osborne (2007) describe that it is important to summarize and reflect upon the experience after the visit. The study pinpointed factors relevant to improve student learning on a field trip to a museum. While on the field trip, students should be encouraged to discuss among each other and with the teacher. The resources on the museum should be designed to evoke curiosity and interest among students. Resources should also engage students in a cognitive way and appear meaningful for them. In a study by DeWitt and Storksdieck (2008) field trips were shown to act motivational on the students, and could also be proven to have long-term impact on the students. DeWitt and Hohenstein (2010) investigated how the teacher-student interactions differed on field trips and in the classroom. According to the study, more students took initiative to discussions while on the field trip, and questions asked by the teachers were more often open-ended.

One common way to achieve the positive effects of out-of-school learning is visits to student labs. Student labs are laboratories located at a university campus with the purpose of visits by secondary school students to perform lab experiments under the supervision of employees of the university. The impact of students' interest in science due to a single visit to student labs have been examined by many. Glowinski and Bayrhuber (2011) researched students' attitudes to science after a student lab visit and did found three factors that affect the students' interest in a student lab. Those are interest in experiments, interest in research and application contexts, and interest in the authentic learning environment. Furthermore, Glowinski and Bayrhuber (2011) found that low long-term interest could be increased by visits to student labs if performed in an efficient way.

Another study on single visits to a student lab by Itzek-Greulich, Flunger et al. (2014) and Itzek-Greulich, Flunger et al. (2015) investigated how much and what students learned in student labs compared to traditional teaching in schools. Three cases were studied: students only being taught at a student lab, students only being taught at school and students being taught in a combination of the school and the student lab. Results showed that students being taught at school only gained the highest chemical specific knowledge of the subject being taught. Secondly followed students being taught in a combination of school and student lab. Students being taught at the student lab only showed the lowest chemical specific knowledge (Itzek-Greulich, Flunger et al. 2014), emphasizing the importance of interaction of the visit to the everyday education. Other measurements in student learning during student lab experiments by Itzek-Greulich, Flunger et al. (2015) were chemical analysis, chemical terms, experimental specific knowledge and declarative knowledge. Students being taught at the student lab showed a higher score on experimental specific knowledge. In the other three measurements did students being taught at school perform the best. Another aspect of student labs mentioned by Itzek-Greulich, Flunger et al. (2015) is the fact that student labs normally are better equipped for more complex experiments than a school laboratory.

The teachers' perception of single visits to a student lab was investigated by Luehmann and Markowitz (2007). Benefits mentioned were increased access to resources and increased student learning and motivation. The teachers also perceived that students gained an understanding of the nature of science and inquiry and developed their ability to scientific reasoning. Luehmann (2009) also researched students' perspective of visits to a student lab. In a survey, students shared that the most important thing they learned during the visit was specific concepts of science, how things work. Students also shared that they learned scientific processes, how to perform parts of the experiment and the general culture of science. Further, the best part of the visit according to the students was to perform specific parts of the experiment or experimenting generally. Luehmann (2009) also investigated the teachers' perceived benefits of the visit further. A positive aspect mentioned by the teachers apart from the earlier mentioned by Luehmann and Markowitz (2007) was students' identity development in science.

In the study by Dabney, Tai et al. (2012), conclusions were drawn on how participation in out-of-school science activities impacts choices in further education and career. The results of the study indicated that students participating in science related out-of-school activities a few times a year is more likely to study science in university than others. Those activities could be science clubs or competitions and reading or watching science related activities for example.

There is a gap in research regarding the impact on students from visits to a university laboratory on a regular basis. Since it can be seen that single visits may increase students' interest (Luehmann 2009, Glowinski and Bayrhuber 2011, Itzek-Greulich, Flunger et al. 2015), it is reasonable to suggest that visits during a longer period of time will increase students' interest more. The study describes in this report does not investigate visits to a student lab by definition. The laboratory the participating students are visiting is a university laboratory, and the biggest difference from the student lab definition is that it is the students' permanent chemistry teacher that is the supervisor during the visits. However, the similarities between student labs and the situation investigated are large and will be supposed to have the same mechanism regarding students' interest.

2.1.2 Role models in science

Even if it is not the main aim of this project to investigate how role models affect students' interest in chemistry and further education in science during university visits, it is of value to consider when investigating the questions of issue in this project. As well as persons can act as role models to help students see themselves in a certain context and visualize goals, visits to a university laboratory may reach the same results.

The impact of role models and culture on students in science classes have been thoroughly researched. Barton and Yang (2000) described the "culture of power", which is when values, believes and acts elevate one group of people over others. This is quite typical in many science classrooms due to the "one right answer"-culture, focusing on memorization and recitation and the image of science as facts only. The culture of power taking place in science classrooms will often distance students from science since they don't get to feel involved and withholds the image of science being a subject for very smart people. This problem could be solved by a more including classroom climate, but also by role models for students. It is important for students to have role models in order to see that they could have a future in science. Buck, Leslie-Pelecky et al. (2002) found that students still have the stereotypical image of a scientist as an old, white man with glasses in a lab coat, which can be quite hard to relate to for many students. The importance of role models have been proved to affect students' choice of career if it is strongly connected with stereotypes of a certain gender (Savenye 1990). Students normally choose careers where they can find role models to identify with, and they only pursue goals and aspirations they can actually imagine possible (Gibson and Ogbu 1991). Zirkel (2002) studied how ethnicity- and gender matched role models affect students. She found results showing that students with at least one matched role model perform better in school. Students with matched role models generally have more goals than students without a matching role model and their goals tend to be more educational and career oriented. Further, Zirkel (2002) found evidence of non-matched role models (that is, role models that does not have the same ethnicity and gender as the student) not having the same positive impact on students as matched role models.

Limited amounts of research have been performed on students visiting a university and how the visit affects students from a role model perspective. During a visit at a university, students can get the possibility to meet researchers that may act as role models in science. Beyond this, students may also develop a stronger interest in further education since they get to experience the situation and see themselves in a university context. For students to experience how it is to perform experiments in a university laboratory could increase the feeling of belonging and therefore the interest in further education in science. The lack of such studies emphasizes the importance of this project.

2.2 Lab experiments as a learning activity

When investigating the research questions of this project, it is also important to account for the fact that the participants of the study are from different schools in Gothenburg. What happens during lessons at school may also affect students' interest in chemistry and further education in science. It is therefore of importance for the project to look in to previous research on how the design of laboratory activities as well as the teacher's acting in the laboratory can affect students. In this chapter, previous research on how the design and performance of lab experiments can affect students' interest is presented.

Laboratory activities have a self-explanatory part of science education and for a long time it was not questioned whether lab experiments were to be a part of the science subjects. Donnelly (1998) concluded from an interview study with secondary science teachers that they found lab experiments to be a crucial part of the chemistry curriculum. Also, students taking part of science education find lab experiments to be a vital part of the course and a learning opportunity. In a study by Broman, Ekborg et al. (2011) 76 percent of the students indicated they learn chemistry well during laboratory activities. Both students and teachers proposed more laboratory experiments as a way of making chemistry education more interesting and meaningful. Whether lab experiments actually improve students' learning and understanding can however be questioned. There are many aspects of the laboratory activity that can affect how much students learn from experiments in education (Hofstein and Lunetta 1982). A weakness with laboratory work described by Berry, Mulhall et al. (1999) is the often occurring focus on simply completing the task in the fastest matter by the students.

One main factor to account for when debating the strengths and weaknesses of lab experiments is the style of the laboratory instruction, which has been proven to have a great impact on the perception of chemistry. Domin (1999) describes four different types of laboratory instructions: expository, inquiry, discovery and problem-based. Expository instructions have been explained as "cookbook instructions". The instruction handed to the students include background information with explanation of the chemistry relevant for the experiment. Further, there is a step-by-step procedure stating exactly what the students should observe during the experiment. The instruction often ends with post-lab questions to be answered. Expository labs have been criticized for not focusing on experimental design and planning, neither deep understanding of the results. There have been statements of no meaningful learning being present at all with expository lab instructions. Inquiry lab experiments (Domin 1999) are characterized by a question for the students to answer. The students need to propose a lab procedure by themselves in order to find the answer. Research has proven inquiry-based instruction to increase positive attitudes towards science among students. However, it has been criticized for being too extensive for students to learn from and not putting enough focus on science content (Domin 1999). As a consequence, discovery instructions (also called guided-inquiry) has been developed. The students are handed instructions for the experiment, but no explanation of what results to expect. The aim is to let the students discover chemical phenomena on their own. With guidance from the teacher the students are supposed to form their own theories and conclusions. Critique towards discovery lab experiments include that all students will not make the discovery at the same time and the possibility of students simply not making a discovery. The forth instruction style described by Domin (1999) is problem-based instruction. It depends on the students understanding relevant chemistry before the laboratory activity. The students are then encouraged to use that understanding to solve a problem presented in the instruction. Part of solving the problem is typically for the students to decide upon a method suitable for the situation. Problem-based, inquiry and discovery instructions have been noted to be more time consuming than traditional expository instructions. On the other hand, all three nontraditional styles of instruction give the students a better understanding of the experiments than expository instructions.

Millar (2004) concludes that the key to promote learning during experiments is the approach of practical work including both action and reflections. Central in the learning process is to discuss what is experienced during and after the experiment to "make sense" of the observations. According to Millar (2004), in some cases the same learning results can be met without practical experiments. If the learning objective is something the students can be assumed to have experienced in everyday life, an experiment to illustrate the phenomenon is not necessary. By getting the students to recollect the experience before a discussion, the same degree of learning can be reached as if an experiment would have been performed. The importance of science experiments arises when the learning objective is likely to be something the students have not observed beforehand.

Factors affecting the students' mental engagement in experiments, and therefore also their learning, have been observed by Berry, Mulhall et al. (1999). A certain degree of content knowledge prior to the experiment is important for the students to be able to draw conclusions and learn from the activity. Students experiencing ownership of laboratory tasks also increases the engagement in and learning from the experiment. Enough time for the students to perform and reflect upon the experiment is also crucial. Further, research claims that it is important that students are aware of the aim of the lab experiment to promote engagement and learning (Berry, Mulhall et al. 1999, Högström, Ottander et al. 2010). Another aspect of student learning during lab experiments is the students' perception of the psychosocial environment of the laboratory classes (Fisher, Harrison et al. 1998). An instrument named Science Laboratory Environment Inventory (SLEI) has been developed by Fraser, McRobbie et al. (1993) to measure the laboratory environment in science classes. Five scales are measured by SLEI: student cohesiveness (extent to which students know, help and are supportive of one another), open-endedness (extent to which the laboratory activities emphasize an open-ended, divergent approach to experimentation), integration (extent to which the laboratory activities are integrated with non-laboratory and theory classes), rule clarity (extent to which behavior in the laboratory is guided by formal rules) and material environment (extent to which the laboratory equipment and materials are adequate) (Fisher, Harrison et al. 1998). Research has shown that the scales in SLEI (mentioned above in section 2.1.1) have positive impact on students' attitudes towards lab experiments. Especially presence of student cohesiveness, integration, rule clarity and material environment in classes promote favorable student attitudes (Fisher, Harrison et al. 1998).

Another factor that affects the students' interest in chemistry is to what extent the education is connected to everyday observations. If students can relate scientific knowledge achieved in school with day-to-day experiences, they are more likely to learn chemistry and remember the knowledge (Braund and Reiss 2006). In the study by Broman, Ekborg et al. (2011) a suggestion to make chemistry more interesting and meaningful was to make the education more closely connected to everyday life. This was suggested by both students and teachers participating in the study. The teacher's interaction with the students in the laboratory also affects the students' interest and learning during experiments. For example, if performing an expository experiment, students can be asked to justify experiment instructions and aim. Teachers may also initiate active reflections upon the aim of an experiment among students (Berry, Mulhall et al. 1999). Högström, Ottander et al. (2010) investigated how teacher-student and student-student interaction contribute to learning during laboratory activities. In order for discussions about chemical concepts to appear during laboratory activities, teacher-student interaction was necessary in most cases. Högström, Ottander et al. (2010) also concluded that it is important to communicate the learning objectives for a lab experiment to the students to promote learning during the activity.

Exactly how the factors correlate and affect students' interest for science has not been researched. It is not possible to detect which of the mentioned factors that will have most impact on students' interest and learning in science from previous research. The aim of this project is not to investigate that question further. However, the previous research presented above will be utilized in Study 2 to account for the risk that the teachers from the two schools may affect the results from Study 1 simply by their way of teaching.

3
Methodology

The methodology of the project is divided in two parts. Study 1 was investigated by an observational study along with a student survey to measure students' interest in chemistry and further education in science. Study 2 was investigated by direct observations and informant interviews with the teachers. The observational study and the direct observations were performed in two schools, described as school A and school B. Students from school A perform lab experiments at Chalmers and students from school B perform lab experiments at a laboratory at the school. Below are the participating schools, the choice of methods and the details of the implementation of the methodology described.

3.1 Participants in the studies

The participants in the studies were students at the science program in two secondary schools in Gothenburg with one class per year in the science program. At school A, there is no availability to perform lab experiments in chemistry due to a lack of laboratories. The school board's solution is to borrow laboratories at Chalmers for the students to perform lab experiments in. The students get to visit Chalmers approximately once a month to perform lab experiments. The students at school A generally come from immigrant families with quite weak socioeconomic backgrounds. At school B, the students perform lab experiments in a laboratory located in the school building approximately twice a month. School B was chosen as a control group for the experiment by Mats Widigson, Center for School Development in Gothenburg (2018). The schools are similar in several aspects: School B is the school with the closest similarities in the students' socioeconomical background to school A in Gothenburg. Further, the admission points for both schools are quite similar. At school A, the mean value of the students' admission points for the science program the last three years have been 233.33, 227.50 and 231.87, and the corresponding numbers at school B have been 228.3, 244.64 and 239.77 (Gothenburg Region 2015, 2016, 2017). These numbers indicate an equivalence of the students in school A and school B. The teachers at both school A and B are the only chemistry teachers at each school, which means they are teaching chemistry to all students participating in the observational study and the observations. How the teachers conduct the experiments are not known and could vary but will be investigated in Study 2. During parts of the studies, teacher students were following the teachers at each school, participating in the day-to-day education.

3.2 Study 1

Research question 1: "Do regular visits to a university laboratory generally affect secondary school students' attitude towards chemistry compared to students performing lab experiments in their regular school laboratory?" were investigated by an observational study and a student survey. Ideally, an experiment where an experiment group and a control group are randomized from a common group should have been used. Experiments as a method is according to Esaiasson, Gilljam et al. (2017) the safest way to reach conclusions of causality. The strength of an experiment is that the researcher can choose which of the factors that may affect the result that should be varied. To vary the chosen factor the experiment group is exposed to a stimulus. An experiment could not be applied in this study since all the students at school A perform lab experiments at Chalmers and there was no opportunity to alter the arrangement so only part of the students would visit Chalmers in randomized groups. Instead, a control group from a different school had to be found and an observational study performed. In an observational study, groups that cannot be randomly selected are observed (Rice 2007). An example could be differences between genders since the participants' genders cannot be randomly selected, or, as in this case, students from different schools.

After recommendations from Widigson (2018), school B was chosen as the control group due to its equalities in socioeconomic backgrounds of the students. A school with similarities in the socioeconomic background was chosen to ensure the highest possible degree of equality of the test group and the control group before the experiment. Also, the admission points for students at the science program at both schools have similarities (Gothenburg Region 2015, 2016, 2017), which indicates the equivalence of both schools. The student groups could not be altered in any way since there is a resistance in the Swedish school system to perform experimentation in the education. Teachers, principals and parents are usually quite afraid of performing experiments in the students' education in case it will affect students' learning in a negative way.

One factor that may affect the result of the observational study is the fact that the students in the test group (the students from school A) did visit Chalmers once for a safety review before the first survey. Ideally the students would have answered the first survey before any exposure of the stimuli (that is visits to Chalmers). Since the first visit took place so early in 2018 there was no opportunity to perform a survey at the time being due to prevailing conditions. How much this impacts the result could be discussed however. Since the only visit the students took part of before the survey was a safety review with no actual laboratory activities, the impact may not be crucial.

Another factor that may affect the result of the observational study is the design itself. A before-and-after design was chosen to be able to control the differences between the test group and the control group before the study. The first survey may affect the students' interest in chemistry and further education in science by itself and therefore affect the study's outcome (Esaiasson, Gilljam et al. 2017). All student surveys were performed in the students' usual chemistry classroom where day-to-day education is performed in school A and B respectively. The fact that the test group and the control group answered the surveys in the same environment could indicate that even if the survey did affect the result it would affect both groups in the same way.

A weakness of the observational study is the low number of students participating in the study (between 20 and 30 students in each class). Esaiasson, Gilljam et al. (2017) states that each group in a study should consist of at least 30-40 persons to reach high power. As discussed above, there was no opportunity to alter the groups or which students to be exposed to the stimuli. There were neither any options to alter the number of participants since the students available for the observational study were the ones in the first grade at both schools. At school A and B there is only one class in each grade at the science program and all students in the first grade were participating in the study. The choice not to let students from grade two and three participate in the study was based upon the risk of older students being exposed to other stimulus outside of the controlled study design. For example, if students participate in events such as school trips or university visits. Further, there would have been no possibility to perform a first survey before the older students' first visit to Chalmers since that occurred over a year before the work with this master's thesis began.

3.2.1 Implementation

The before-and-after design to investigate the students' interest in chemistry and further education in science and how these are influenced by laboratory activity at a university is visualized in figure 3.1 below.

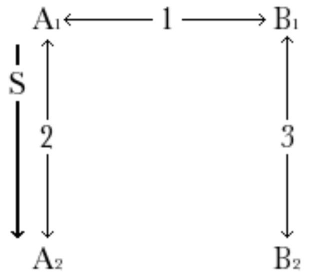


Figure 3.1: Visualization of the study design. A_1 and A_2 represents the measurements (surveys) in the test group from school A before and after the exposing of the stimuli (S). B_1 and B_2 represents the measurements (surveys) in the control group from school B. 1, 2 and 3 represents the comparisons of results that were made.

The study setup had three phases: initial student survey (A_1 and B_1), exposing of stimuli for the test student group (S) and concluding student survey (A_2 and B_2). The stimuli that the test group was exposed to is regular visits to Chalmers to perform lab experiments in a university laboratory. The control group did perform lab experiments at school B during the period. Numbers 1, 2 and 3 in figure 3.1 above represents the comparisons of results that were made. The aim of the study design was to measure the impact on students' interest in chemistry and further education in science by exposing the stimuli. By measuring the groups' interest before (A_1 and B_1), the starting points of the groups could be compared (1). After the second measurements (A_2 and B_2), the impact on students' interest could be observed by comparing the first and the second survey (2 and 3) for the two groups.

The survey was answered by the students in the test group and control groups in the beginning and end of the observational study. The students were asked about their thoughts about further education and research in science. The students were also asked some strictly chemistry-oriented questions in the survey as well as questions that investigated the students' interest in chemistry. There were also questions about the students' background and families. The survey consisted of 13 questions in total and is presented in its original Swedish form in appendix A.1.1. An English translation of the survey is presented in appendix A.1.2. The aim of the survey was to measure student's interest in chemistry and further education in science in order to answer research question 1.

The initial survey was performed November 6^{th}, 2018 by 29 students in the test group at school A and December 12^{th}, 2018 by 23 students in the control group at school B. Before the initial survey, the students in the test group had visited Chalmers once for a safety review and demonstration. During the time between the surveys the students in the test group visited Chalmers to perform the lab experiments approximately once a month. The students in the control group performed lab experiments approximately twice a month in the laboratory located at school B. The second survey was performed April 9^{th}, 2019 by 21 students in the test group at school A and April 10th, 2019 by 24 students in the control group at school B. All surveys were answered by the students in school A respectively school B in the students' normal chemistry classrooms where day-to-day education takes place.

3.2.2 Statistical analysis

The results from the survey were analyzed statistically by a difference-in-difference analysis using the software R and RStudio after the implementation of the observational study. A difference-in-difference analysis measures two differences in the observational study: the differences between the two participating groups, and the differences from one occasion to another within one group (Gertler, Martinez et al. 2016). When applying a difference-in-difference analysis, it is assumed that the interest among students in the two groups would increase parallel without the applied stimuli. The analysis then measures the impact of stimuli on the test group as the further increase of interest above the parallel increase (Gertler, Martinez et al. 2016). The desirable results from the analysis is visualized in figure 3.2 below.

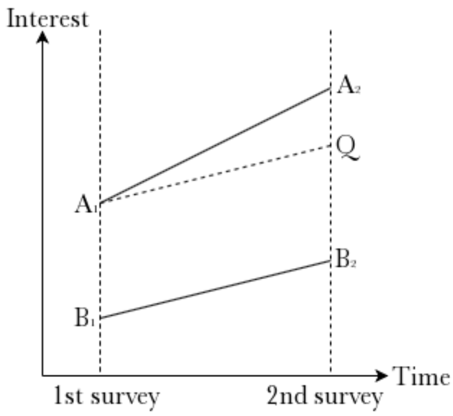


Figure 3.2: Example of how the result from a difference-in-difference analysis could be visualized. A_1 and A_2 represent the measurements (surveys) in the test group from school A before and after the exposing of the stimuli (performing lab experiments at Chalmers). B_1 and B_2 represent the measurements (surveys) in the control group from school B. Q represents the results from the second survey in school A that would have been expected without the exposing of stimuli.

The potential increase of interest in the control group is visualized by the line B_1B_2 and the parallel increase of interest in the test group is visualized by the dotted line A_1Q in the figure. The desired difference-in-difference between group A and B is visualized by the line A_1A_2, which can be seen to have a steeper slope than B_1B_2, which would indicate an even higher increase of students' interest for chemistry and further education in science.

When calculating the difference-in-difference, a mathematical model on the form

$$y = x_0 + b_1 \cdot x_1 + b_2 \cdot x_2 + b_3 \cdot x_3 + e$$

was used. Where y represents the outcome variable (the students' indicated interest in the answers from the survey). x_1 is a control variable that is given the value 1 for students at school A and 1 for students at school B. x_2 is another control variable that accounts for the time, it is given the value 1 for all answers from the second survey and 0 for all answers from the first survey. x_3 is a third control variable that is given the value 1 if both x_1 and x_2 have the value 1 (that is, for the answers from school A students in the second survey). e represents the error in the model and x_0 is a constant that accounts for the estimated value for y when x equals zero (in this case x_0 was a vector of ones). By calculating the coefficient b_3 with the ordinary least square method, it can be observed whether the groups have been affected differently during the experiment by calculating a significance level (Agerberg 2019). The significance level is defined as the certainty that it could be argued that there is a difference between the groups. It is generally accepted that a significance level of 95 percent is required to be sure there is a significant difference (Rice 2007).

3.3 Study 2

Since there is a risk that the result from Study 1 can be affected by the fact that the control group in the observational study is from another school and has another teacher, Study 2 was interesting to perform. As examined in section 2.2, what kind of lab instructions the students receive and the teacher's actions in the laboratory affect students' interest in chemistry. Study 2 was designed to answer research question 2: "How does the lab situation performed at Chalmers differ to the lab situation at a laboratory located in an upper secondary school in regard of the design of lab experiments and the teachers' acting?". To investigate this, direct observations during lab experiments complimented by informant interviews with the responsible teachers were explored in the second study. When planning the observations inspiration was received from ethnological studies since this part of the study to a certain degree can be considered ethnological (O'Reilly 2009).

Direct observations are an efficient way of investigating processes or structures since these can be hard to describe in words (Esaiasson, Gilljam et al. 2017). Even if the objectives could be described, there might be a difference between what is said and what is actually done (O'Reilly 2009). Observational investigations are a common approach in pedagogical studies (Esaiasson, Gilljam et al. 2017). Hence, observations were chosen over structured interviews with the teachers to investigate how the laboratory situation at Chalmers differs from a traditional secondary school laboratory situation.

Factors concerning the post reflections of the lab experiments can to some extent be hard to investigate during observations. Therefore, they were further discussed with the teachers in informant interviews to clarify the degree of presence of reflection upon experiments before and afterwards. The choice to investigate those further by informal conversation rather than formal interviews was based upon the fact that there was no need for standardized interview questions. The need of conversation and further investigation varied for each observational visit, so prepared questions were not an alternative.

When performing direct observations, the length of the observation phase has to be decided upon. Starting observations in a new group, it takes time to normalize the situation and get the group customized to the observers' presence. In the beginning, the observer may affect the happenings and actions barely by being present. Ideally, a getting-used-to phase should be performed before the actual observations start (O'Reilly 2009). There were limited opportunities to observe the laboratory activities at Chalmers since the students only visit roughly once a month. Therefore, the getting-used-to factor couldn't be taken in to account when designing the direct observations. The impact on the results are however minimized since the same observational patterns were used at both Chalmers and school B. Hence, it could be argued that the short getting-used-to phase would affect both classes in the same way.

From the previous research discussed in section 2.2, seven observational factors to focus upon during observations were chosen. As discussed by O'Reilly (2009), when the focus of the observations is decided upon before they are performed there is a risk for tunnel vision. When searching for specific happenings, the observer may close his or her eyes for other behavior or happenings that does not directly correlate to what he or she is scouting for. O'Reilly (2009) describes it as "in the same way that what is seen affects what gets written down, what gets written down affects what is seen".

The aim of the observations was not to perform a full-featured ethnological study, and therefore it won't be evaluated as such. There are however some aspects of ethnography that are of relevance to discuss for this study. When discussing ethnographical studies, insider ethnographies is a term describing observations in an environment where the observer already is a participant of the everyday life. O'Reilly (2009) discusses how being an insider ethnographer might make it hard to perform objective observations since the environment is so familiar to the observer. The observer in this study has prior experience of laboratory activities at both Chalmers as a university student and at upper secondary school laboratories as a teacher. This could have impacted the results of the study, but since the observer had the observational factors to focus upon during the observations, the impact should not be that crucial.

When performing observations there is a question whether the study should be covert or not, that is, whether the participants should know they are being observed or not (O'Reilly 2009). At the beginning of every observational occasion the observer introduced herself and that she was visiting to see what was happening during the laboratory activity. There is no doubt that the participants in the study knew they were being observed. However, exactly what was being observed during the observations was not communicated to the teachers or the students. From an ethical perspective, the observer should be as open as possible while still enabling the questions of issue to be investigated (O'Reilly 2009). In this study, if the teachers had known exactly what was being observed (mainly the seven factors mentioned in section 3.3.1), maybe they would have altered their acting during the laboratory experiment being observed. The choice to not be completely open about the aim of the observations was made since the circumstances were not considered an unethical situation. It would not do any harm to teachers and students if they were not completely aware of the observational aim.

Despite the weaknesses of the observational design, it is a good way to investigate the differences between the laboratory activities at Chalmers and school B. There are factors that may affect the observations being made and the acting of students and teachers in the laboratories. These are, however, so small and so similar between the two laboratory settings that the observations will be efficient to map the differences. It is of higher interest to investigate how the laboratory activities compare to each other rather than what exactly is happening during lab experiments. This since the direct observations are performed to validate and explain the results of Study 1.

3.3.1 Implementation

To observe how the lab situation differs, direct observations were performed with the intention to map the differences. The observations were performed in student groups in second grade from both schools, in order to not affect the result of Study 1 by being present in the laboratory with the students from the test group and control group according to the Hawthorne study (Eriksson-Zetterquist, Kalling et al. 2015). The teacher and students from school A were observed while performing lab experiments in the Chalmers laboratory. To compare the laboratory activities the teacher and students from school B were observed while performing lab experiments in a laboratory at school B.

According to the research presented in the previous research of this report, seven focus areas or factors were compiled to scout for during observations in the laboratories. All of these factors have been proved to have a positive impact on students' interest and or learning in chemistry in previous research (Fisher, Harrison et al. 1998, Berry, Mulhall et al. 1999, Domin 1999, Millar 2004, Braund and Reiss 2006, Högström, Ottander et al. 2010, Broman, Ekborg et al. 2011). These factors were assessed to be the ones with the biggest impact on students' interest and learning of all of the research presented in section 2.2. The choice to observe these factors in particular was also based on the assessment that these are the ones most likely to differ between the laboratory activities at Chalmers and school B. This assessment was made by previous experiences from laboratory activities at Chalmers and different secondary schools. The main focus during observations was to identify if there was a presence of these factors at the laboratory setting. If other happenings of interest were noticed during the observations, they were noted for further analyzation.

Focus factors during observations:

- If the lab instruction given to the students was either inquiry, discovery or problem-based instead of the traditional expository style.
- If the purpose of the laboratory activity was clearly communicated to the students.
- If the experiment was related to the students' everyday life and day-to-day observations.
- If the rules in the laboratory were communicated and if the teacher was making sure they were followed.
- If the teacher asked elaborate questions that encouraged students to reflect during the experiment.
- If the laboratory was well-suited for the current experiment.
- If time was assigned for reflections after the experiment.

The direct observations were performed during the period of March 11th to April 8th, 2019. The teacher and second-grade students from school A were observed during two visits to Chalmers and the teacher and second-grade students from school B were observed during two lab experiments in the laboratory in school B. In addition to the observations, informant interviews with the teachers were performed before, during and after the visits to further investigate the factors above.

4

Results

The results of the studies showed small differences between the students from school A and students from school B both before and after the observational study (Study 1). Further, some differences could be observed during direct observations during lab experiments at the schools. This chapter aims to present the results of the studies in detail. Because of the extensiveness of the study and the need to protect the participants anonymity, the results have been compiled for presentation in this report. No individually answered surveys or observation notes are presented in the report.

4.1 Study 1

The surveys answered by students in the test group (school A) and control group (school B) have been compiled and the results are presented below. For the questions with options from 1 (not interested at all) to 5 (very interested) a mean value of the answers from each class has been calculated. In section 4.1.1 the background of the students, according to the answers from the first survey, is presented. Students' interest in science and chemistry is presented in section 4.1.2 and students' interest in further education is presented in section 4.1.3.

4.1.1 Students' backgrounds

Some questions in the survey aimed to investigate the backgrounds of the students and their families. These questions were only asked in the first survey since they are not considered variables in the observational study. The questions had the purpose of comparing the student groups before the study in order to be able to evaluate the choice of the control group.

In school A, 45 percent of the students were boys and 55 percent girls. In school B there were 57 percent boys and 43 percent girls among the students. Further, the students were asked what profession and level of academic degree their parents hold. The results from these questions have been summarized to answer how many students have one or two parents with a university degree. In school A, there was one student with two parents holding a university degree, nine students with one parent holding a university degree and eleven students had no parents that did hold a university degree. In school B, the corresponding numbers were six students with two parents holding a university degree, and seven students each with one or no parents holding a university degree.

In conclusion, there were some differences between the group's constellations regarding the students' gender or family's academic backgrounds. These are however considered small in combination with the results from the first surveys presented in 4.1.2 and 4.1.3, the students' socioeconomical backgrounds and the schools' admission points.

4.1.2 Students' interest in chemistry

The first questions in the survey aimed to investigate the students' interest in chemistry and science. The mean values for the questions in each survey have been calculated and compared as described in section 3.2.1. The results are presented in table 4.1 below. A_1 & A_2 represents the first and second survey in school A and B_1 & B_2 represents the first and second survey in school B. The differences calculated and presented in the table are the difference between school A and school B from the first survey ($|A_1 - B_1|$), the difference between the first and the second survey in school A ($A_2 - A_1$) and the difference between the first and second survey in school B ($B_2 - B_1$).

	School A		*School B*		*Difference between measurements*		
	A_1	**A_2**	**B_1**	**B_2**	**$\|A_1 - B_1\|$**	**$A_2 - A_1$**	**$B_2 - B_1$**
Q1. How much do you enjoy going to school?	3.8	3.7	3.7	3.7	0.1	- 0.1	± 0
Q2. How much do you enjoy what happens in lessons at school?	3.2	3.0	3.2	3.4	0	- 0.2	+ 0.2
Q3a. How interested are you in science subjects?	4.2	4.0	4.1	4.1	0.1	- 0.2	± 0
Q3b. How interested are you in other subjects?	3.9	3.9	3.7	3.6	0.2	± 0	- 0.1
Q4a. How interested are you in lab experiments in chemistry?	4.1	4.0	4.2	4.0	0.1	- 0.1	- 0.2
Q4b. How interested are you in theoretical chemistry knowledge?	4.0	3.5	3.8	3.4	0.2	- 0.5	- 0.4
Q4c. How interested are you in what drives different chemical phenomena?	3.8	3.6	3.8	3.5	0	- 0.2	- 0.3
Q4d. How interested are you in explaining everyday observations with chemistry?	3.8	3.5	3.6	3.8	0.2	- 0.3	+ 0.2

Table 4.1: Survey answers regarding students' interest in chemistry and science. 1 represents not interested at all and 5 represents very interested. The differences presented shows the three measurements described in section 3.2.1.

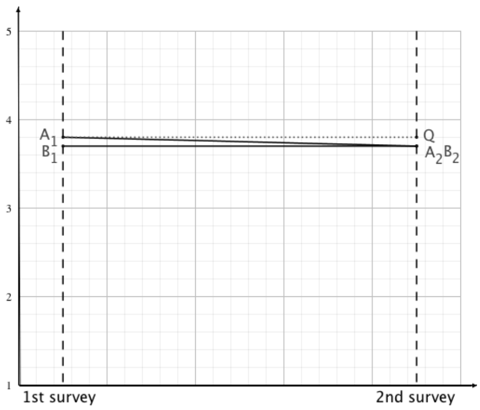
Concluding the results in table 4.1, it can be seen that there are small differences between school A and school B before the experiment, validating the equality between the test group and the control group. Further it can be seen that the differences between the schools after the observational study are not that large. The significance from the statistical analysis of the results are presented in table 4.2. The highest significance level is 74.5 percent for the question regarding the students' interest in theoretical chemistry knowledge. However, it is not low enough to ensure that the measured differences are significant at a 95 percent level.

	Significance level
Q1. How much do you enjoy going to school?	5.1 %
Q2. How much do you enjoy what happens in lessons at school?	40.9 %
Q3a. How interested are you in science subjects?	59.3 %
Q3b. How interested are you in other subjects?	9.9 %
Q4a. How interested are you in lab experiments in chemistry?	9.2 %
Q4b. How interested are you in theoretical chemistry knowledge?	74.5 %
Q4c. How interested are you in what drives different chemical phenomena?	26.6 %
Q4d. How interested are you in explaining everyday observations with chemistry?	17.3 %

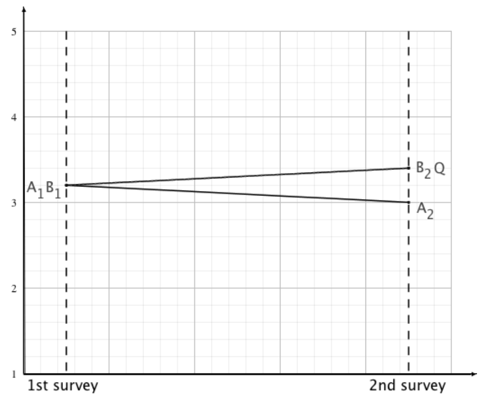
Table 4.2: The calculated p-values from the difference-in-difference analysis of each question. None of the significance levels are 95 percent or higher that is the limit for significant difference.

To further visualize the results, they have been plotted to show the difference-in-difference found in the analysis. The result plots are presented in figure 4.1 on the next page. As it can be observed in the figure, there are no obvious differences between school A and B. That is, there are no distinct differences between the dotted trend line A_1Q and the actual line A_1A_2.

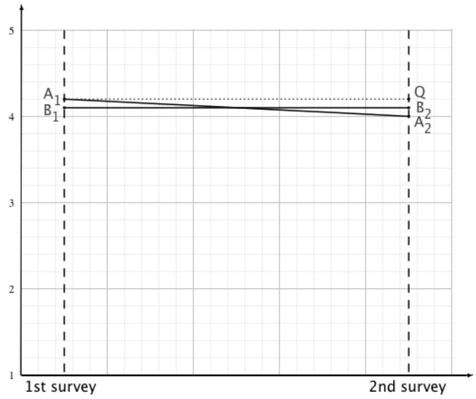
To investigate students' interest in chemistry in a qualitative manner rather than a quantitative, the students were asked in an open question if they found it important to learn chemistry, and in that case why. The answers from all surveys are presented in appendix A.2.1. Summarizing the answers, there were some small similarities between schools in why students find chemical knowledge important. If there was an increase or decrease in these trends cannot be determined however. Both students from school A and B mentioned the importance of chemical knowledge to understand the world and to learn about chemical substances. Also, students from both schools mentioned the importance of learning chemistry for further education. In the first survey, several of the students from school A mentioned the importance of chemical knowledge when developing new medicines and for other use in healthcare. However, this was not seen in the second survey.



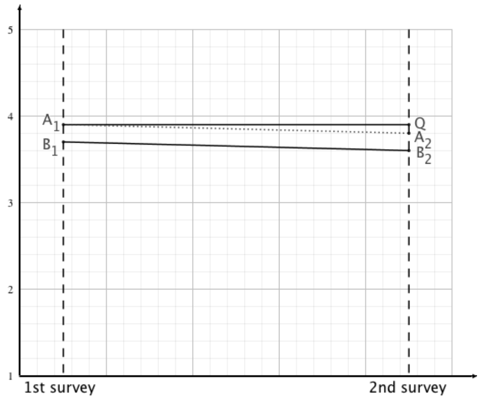
(a) Q1. How much do you enjoy going to school?



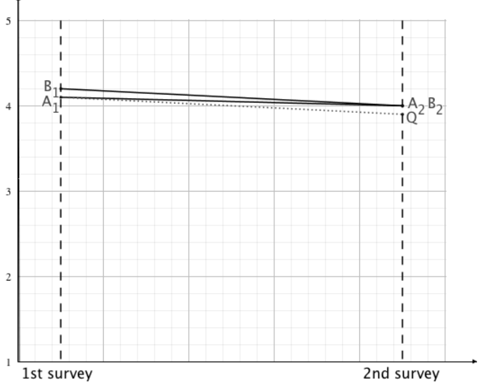
(b) Q2. How much do you enjoy what happens in lessons at school?



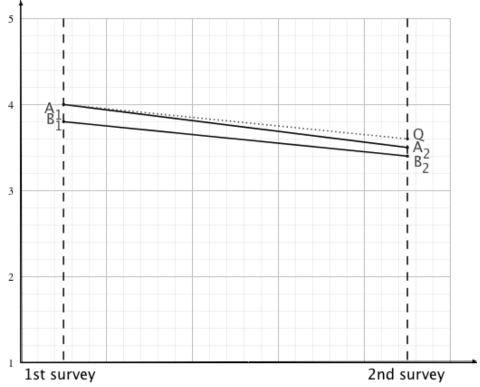
(c) Q3a. How interested are you in science subjects?



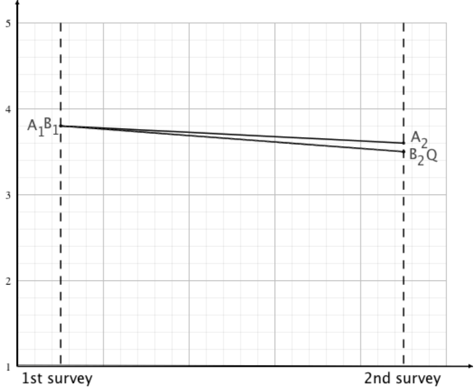
(d) Q3b. How interested are you in other subjects?



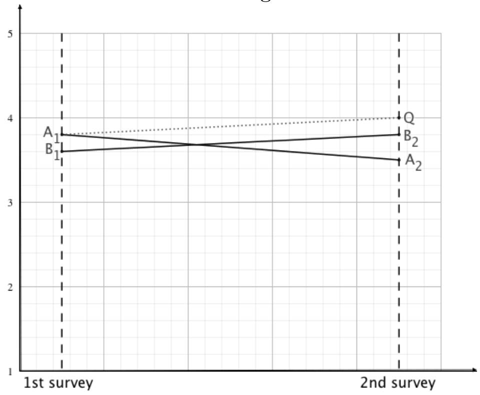
(e) Q4a. How interested are you in lab experiments in chemistry?



(f) Q4b. How interested are you in theoretical chemistry knowledge?



(g) Q4c. How interested are you in what drives different chemical phenomena?



(h) Q4d. How interested are you in explaining everyday observations with chemistry?

Figure 4.1: Visualization of the survey results regarding students' interest in chemistry.

4.1.3 Students' interest in further education

The second part of the survey aimed to investigate the students' interest in further education. The calculated mean values from the answers are presented below in table 4.3. The labels in the table are the same as the ones used in table 4.1.

	School A		*School B*		*Difference between measurements*		
	A_1	**A_2**	**B_1**	**B_2**	**$\lvert A_1 - B_1 \rvert$**	**$A_2 - A_1$**	**$B_2 - B_1$**
Q6a. How interested are you in starting to work directly after school?	2.3	2.3	2.2	2.2	0.1	± 0	± 0
Q6b. How interested are you in studying at a university?	4.6	4.3	4.7	4.5	0.1	- 0.3	- 0.2
Q7. How interested are you in studying science at a university?	4.5	4.2	4.2	4.2	0.3	- 0.3	± 0
Q8. How interested are you in performing research in the future?	3.5	2.7	3.5	3.0	0	- 0.8	- 0.5

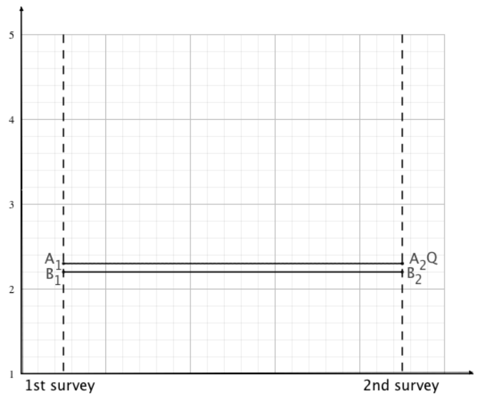
Table 4.3: Survey answers regarding students' interest in further education and research. 1 represents not interested at all and 5 represents very interested. The differences presented shows the three measurements described in section 3.2.1 above.

Concluding the results in table 4.3, it can be seen that there are small differences between school A and school B before the observational study, further validating the equality between the test group and the control group. Further it can be seen that the differences between the schools did not change that much after the observational study. For the question regarding students' interest in performing research, the calculated significance level is 83.2 percent, which is considerably high compared to the other numbers, but still not in the 95 percent level to ensure that it is a significant difference between the groups. The significant levels calculated in the statistical analysis are presented in table 4.4 below.

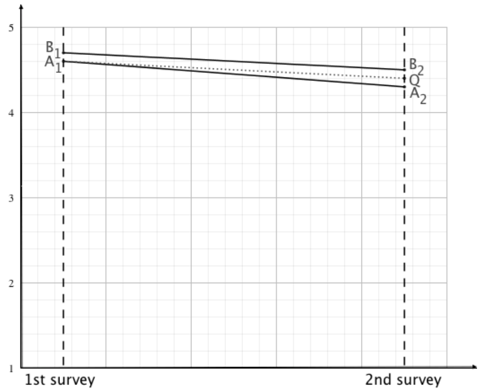
	Significance level
Q6a. How interested are you in starting to work directly after school?	2.9 %
Q6b. How interested are you in studying at a university?	45.0 %
Q7. How interested are you in studying science at a university?	35.8 %
Q8. How interested are you in performing research in the future?	83.2 %

Table 4.4: The calculated p-values from the difference-in-difference analysis of each question. None of the significance levels are 95 percent or higher that is the limit for significant difference.

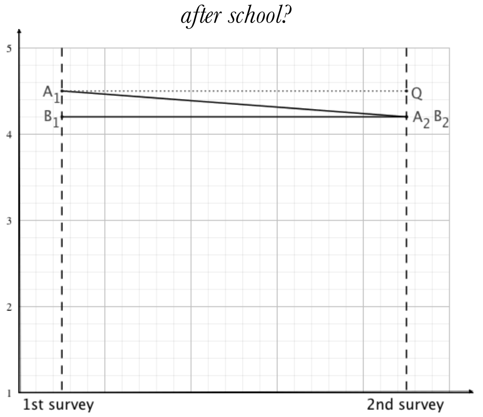
The results from the statistical analysis regarding the students' interests in further education in science have also been plotted. In the plots, presented in figure 4.2 on the next page, it can be seen that there are no obvious differences between school A and B.



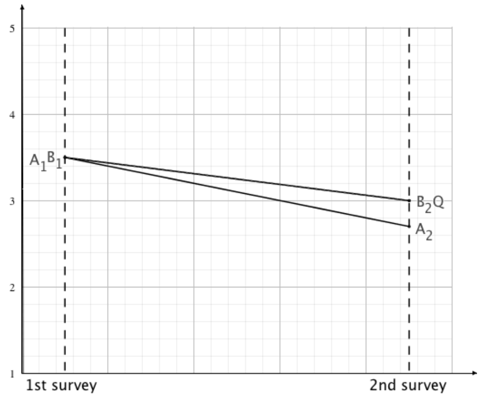
(a) Q6a. How interested are you in starting to work directly after school?



(b) Q6b. How interested are you in studying at a university?



(c) Q7. How interested are you in studying science at a university?



(d) Q8. How interested are you in performing research in the future?

Figure 4.2: Visualization of the survey results regarding students' interest in further education in science.

Regarding students' interest in further education in science and research an open question was included in the survey. The students were asked what they think a researcher in chemistry does. The answers from all surveys are presented in appendix A.2.2. It was seen that students from both school A and B mentioned that they think researchers spend time finding new chemical substances in both surveys. A number of students from both schools also wrote that they do not know what a researcher in chemistry does, or simply did not answer the question. The interest in medicine and healthcare within the student group from school A was apparent in this question as well. However, the interest was seen in the second survey as well, and some students from school B also mentioned the development of new medicines in the second survey. Further, some students from school B mentioned in the second survey examples of chemical researches finding solutions to make the life quality for the society better.

4.2 Study 2

The second study in the project aimed to investigate which differences can be seen between the laboratory activities at Chalmers and school B according to previous research regarding the impact on students' learning and interest due to the design of lab experiments and the teachers' acting.

Thorough notes were taken during the direct observations. The notes were analyzed and compiled shortly after the occasions and are presented below as observation number one to four. The full notes from the observations are not presented in this report in order to protect the participants anonymity. The laboratory instructions handed to the students during the laboratory experiments are presented in English in appendix A.3. In section 4.2.1 is a summary of the results from Study 2 presented to concretize which observational factors were present during the laboratory activities.

Observation 1: Chalmers laboratory

March 11th, 2019
Present: Teacher A (TA), Teacher student A (TSA), 14 students from school A

The lab experiment being performed during the observation was to investigate whether rice, flour and chickpeas contains protein. According to TSA the students had a task before the experiment to read the laboratory instruction and write down a flowchart for the implementation in their own words. An English version of the instructions handed to the students are presented in appendix A.3.1 and it is a mix of expository and discovery style. After the students had settled down in the laboratory, TSA started the experiment by a safety review talking about the chemicals being used in the experiment ($NaOH$ and $CuSO_4$). TSA stated that sodium hydroxide is corrosive and that the students needed to be careful. TSA stretched the importance of safety equipment: robes, glasses and gloves. TSA told the students what to do if they got sodium hydroxide in the eyes and showed the eye shower. Further, TSA talked about copper sulfate being hazardous for the environment and the need to dispose the chemicals in a certain container. After the review, TA let the students divide themselves in groups of three for the experiment. Before the students started the practical work, they came up with a hypothesis of the expected outcome of the experiment. During the experiment, TSA were making sure that all students were wearing safety glasses and handed the observer a pair as well to state an example.

In the first part of the experiments where the students had to recall the instructions and find all requested equipment the laboratory activity was quite jumbly. TA and TSA had to focus on reminding the students of wearing the safety equipment and helping students find equipment. Both TA and TSA made sure the students were focusing by asking questions such as "Where are your measuring cylinder?" or simply "How is it going?". TA and TSA were circling the laboratory and answered questions from the students. After a while when a group of students realized that the volumetric flask being used was too small for the substances to mix properly. TA started to search for bigger containers to be used instead, while TSA suggested to the students to use a small beaker in the meantime.

Most of the focus of TA and TSA seemed to be to answer or confirm questions from the students, mostly regarding the method. The conversational patterns mostly followed the structure of students asking a question followed by TA/TSA answering and giving an explanation. During the experiment, TA and TSA continued to circle the laboratory and check in on the students. TA quite often checked the students' method and asked control questions such as "Have you added aluminum in that?". Often, focus seemed to be on making sure the students were performing the experiment correctly in order to achieve "the right" results. TA was quite "hands on" in the instructions, often showing the students how to perform a step in the experiment. TSA put much focus on helping the students with the disposing of chemicals, explaining how the students should perform the procedure while they tried themselves.

After a while, when the students started to get results from the experiment. TA and TSA spent time explaining for most groups why they got the results they did. They also explained what the next step of the experiment was and what results the students could expect to observe in the groups. When the students had performed all experiments, they were encouraged by TA to sit down and reflect upon the results and their meaning. There was plenty of time for the students to analyze the results. TA could be observed talking to one group about the aim of the experiment and formulated clearly what the students were to write as aim in their report.

Observation 2: School B laboratory

March 11th, 2019
Present: Teacher B (TB), Teacher student B (TSB), 12 students from school B

The experiment being performed during the observation was to measure density, boiling point and solubility for an unknown organic substance and by these characteristics identify the substance. The students had no prior information of the experiment and were handed the laboratory instructions at the start of the lesson. The laboratory instructions used are most accurately described as a mix of expository and discovery instructions and are presented in an English translation in appendix A.3.2. At the beginning of the lesson, TB wrote the goal of the experiment on the whiteboard: "To identify an unknown organic substance by density, boiling point and solubility". The students were divided in groups of three by TB, making sure to split up friends. Simultaneously, TSB collected the students' phones. TB started the experiment by a safety review, stating the need of caution when handling organic substances. TB told the students that organic substances are fire hazardous and have fumes that should not be inhaled, stretching the importance of safety equipment and handling chemicals inside the fume cupboards. TB also stated that the students needed to show TB or TSB their boiling arrangement and get a thumbs-up before they could start their Bunsen burner. After the safety review, TB locked the door to the laboratory in order to keep late students out since they were not allowed to perform the experiment after missing the review.

The students then started to perform the experiment. The first part of the experiment was quite chaotic with students retrieving safety equipment, reading instructions and searching for the right laboratory equipment. TB retrieved many questions of the experiment, such as "We're supposed to have one of these, right?". Such questions were answered by TB with a yes or a no, followed by an urging to read the instructions. TB had to explain for some groups exactly what they were to do: "You are to find what substance of all the ones in this list that I have handed you by testing these four things, it says exactly what to do here". Throughout the experiment, TB encouraged the groups to make sure all students were involved in performing the experiment. Most of the questions asked by students were of the conformational type: "we are supposed to do like this, right?" and were mostly answered by a quick yes or no followed by a brief explanation from TB or TSB. During the experiment, TSB was mostly concerned by helping all groups to get the boiling equipment set up in a proper way.

The safety equipment was used sporadically during the experiment. TB was observed remembering one student to wear his robe, and many students, including TB, was wearing the safety glasses on the forehead. One student handling chemicals without his glasses were told "Where are your glasses? Always wear glasses when performing experiments" by TB. During the experiment, most student groups worked quite independently. TB had to spend some time talking to students arriving late. One group was not as independent, and received greater attention from TB with questions like "How is it going? Aren't you supposed to weigh this now?". Both TB and TSB were quite "hands on" while explaining, often showing students how to perform parts of the experiment.

After a while, the groups started to retrieve some results from the different measurements. TB asked one group "Have you calculated the density? What did you get?" and got the answer "It is 0,79, so it has to be either acetone or ethanol". This was followed by TB stating: "That is why we need to measure several characteristics to decide what substance we have". TSB were observed asking a group "What do you think will happen now?" when they had set up the boiling equipment. The students did not now, so TSB explained the function a water bath. TB were also observed asking the students questions about what they thought would happen or why they were using a specific method. When the groups started to finish the experiment, TB encouraged them to analyze the results to decide upon what substance they had. TB checked upon every group and asked them to explain how they thought when figuring out what substance they had. When the groups had explained their chain of thought and conclusion, TB confirmed if they were right and then the students got to leave the laboratory. In these discussions, TB asked many elaborate questions such as "Why do you think it is ethanol?" or "Could it be another substance?".

Observation 3: School B laboratory

April 1, 2019
Present: Teacher B (TB), Teacher student B (TSB), 11 students from school B

The experiment being performed during the observation was to measure the activity of enzyme activity in yeast as a catalyst of the deconstruction of hydrogen peroxide to water and oxygen. The instructions handed to the students are presented in English in appendix A.3.3 and are of expository style. The goal of the lesson was written on the board: "Performing experiment + results". TSB started the experiment with a review of enzymes, bringing up that they work as catalysts. Further, TSB described catalase that catalyzes the reaction when hydrogen peroxide deconstructs to water and oxygen. TSB also talked about the role of catalase, that it can be found in most living organisms. TSB continued with the safety assessment of the experiment, mentioning the importance of safety equipment since H_2O_2 can be corrosive and bleach clothes. Further, TSB described for the students how to create a dilution series and the rest of the steps of the experiment and which results to look for.

When starting the experiment, the students' formed groups by themselves and started looking for the experimental equipment needed. TB and TSB circulated between the groups, helping them to get started and in some cases explaining the method one more time. While explaining, both of them showed what they meant while pointing at the equipment, but without performing the task for the students. TB also reminded all students to wear safety glasses on several occasions, which was needed since students took them off repeatedly. The student groups seemed to need support from TB and TSB in the beginning of the experiment to get it set up properly and understand all steps of the method. Afterwards, while starting to measure the time repeatedly, the groups worked quite independently. TB and TSB continued checking in on all groups, asking questions such as "You're done? Nice! Did you understand what was happening?", going in to an explanation of the chemical reaction.

When most groups were finished, the discussions between TB/TSB and the students shifted towards questions such as "What factors do you think affects the results?". TSB also showed a demonstration of the reaction with 30 % H_2O_2 instead, how it reacts even faster. One student asked what would happen if he poured the whole beaker of yeast into the test tube with H_2O_2 (low concentration) and was allowed to try by TSB. They performed the added experiment, but no further discussion about the results took place. As the student groups finished the experiment, the focus in the classroom got lower and students did not start to answer the questions until told to do so by TB/TSB. The student had some time in the end of the lesson to answer questions designed to reflect upon the experiment performed and how the enzyme activity was affected by concentration of H_2O_2. According to TB, they were to continue the discussion about the questions the next chemistry lesson.

Observation 4: Chalmers laboratory

April 8, 2019
Present: Teacher A (TA), 13 students from school A

During the observation the students were performing an experiment to determine which one of three possible reactions that takes place when sodium bicarbonate is heated. The instructions handed to the students were of expository style and are presented in appendix A.3.4. TA started the experiment by going through the experiment, making connections to what they had been working with in advance: chemical calculations and analytic chemistry. TA drew connections from analytic chemistry to health care (blood and urine samples) and environmental measurements. Further, TA also described in detail the experiment the students were to perform and showed some of the critical parts of the experiment. TA also explained the characteristics of heated sodium bicarbonate and how it is utilized in baking.

When the students started with the experiment, TA reminded them of safety glasses, and from that point all students and TA wore the glasses all through the experiment. Staring up the experiment, the students were a little bit hesitant while reading the instructions and searching for the equipment needed. TA helped them by explaining any uncertainties in the method and showing were to find certain equipment. Further, TA had to check in on most groups and help them to achieve an efficient arrangement with the Bunsen burner. When the student groups had everything organized, they worked independently while heating the sodium bicarbonate. When the heating process was done, one group dropped their crucible when trying to place it in the cooling container. TA confronted them and empathized the importance of pausing and thinking ahead while preforming lab experiments. TA continued by showing the rest of the students how to hold the crucible with the pliers properly in order to put it down safely.

Most focus of TA during the experiment seemed to be to circulate the laboratory keeping an eye on the students. Now and then TA checked in on the groups asking them how the experiment went and helping some groups getting the burner to work more efficient. Most of the interaction between TA and the students focused on the performance of the experiment. When the students started to finish the experiment, TA remembered the groups to clean up while the salt was cooling. Afterwards, when the students started to perform the calculations, the interaction with TA continued in the same pattern with TA explaining for many groups how to calculate and not asking elaborate questions. In the end of the lesson the students had no hurry in calculating, and TA were checking in on every group to discuss their answers and if they had performed the calculations correctly. The students also had the task to write a report on the experiment afterwards.

4.2.1 Summary

The direct observations and informant interviews in Study 2 aimed to investigate the presence of the seven factors (section 3.3.2) in the laboratory settings. To concretize the results, they have been summarized in table 4.5 on the next page.

	School A at Chalmers		*School B*	
	Observation 1	**Observation 4**	**Observation 2**	**Observation 3**
Instruction style	Expository and discovery	Expository	Expository and discovery	Expository
Purpose was communicated			X	
Connections to everyday life	X	X		
Rules were followed up	X	X	/	/
Elaborate questions			X	/
Suitability of laboratory	/	/	X	X
Time to reflect of experiment	/	X	X	/

Table 4.5: Summary of the factors observed in laboratories during observations in Study 2. X means that the factor was present to a high degree during the laboratory situation and / that the factor was present to a moderate degree.

Concluding the results in table 4.3, there were some differences between the laboratory activities in school A (Chalmers) and school B. The larger differences include that the teacher from school A made clearer connections to students' everyday life in the experiments and was a little stricter with following up laboratory rules. The teacher from school B however, was more concerned with communicating the purpose of the experiments and asking elaborate questions to the students. In school B, the laboratory also was more suitable for the current experiment meaning that the relevant equipment could be found easily, and no changes had to be made from the instruction given to the students. In both schools, students were given time to reflect upon the experiment in the end of each lesson and the instructions given to students were of the same styles.

5

Concluding discussion

In chapter 4 the results from the two studies were presented. No significant differences in interest between the students from school A and school B could be observed. There are, however, some aspects of the results that can be discussed and further contextualized. The conclusions of the research questions are presented in section 5.2 and further research connected to this project that would be of interest to perform in the future is presented in section 5.3.

5.1 Discussion

As a first stage of result analysis, the choice of control group is evaluated. The characteristics of the two groups such as students' socioeconomical background and the schools' admission points indicated similarities between the students in school A and school B. Further, the comparisons between the schools from the first survey showed considerable similarities between the students' answers, which confirms the equality between the student groups participating in the observational study.

In Study 2 however, some differences regarding the way teachers from school A and school B chose to teach could be observed. Teacher A and B had different strengths in their way of teaching that may affect students' interest in chemistry. Since there is no previous research that weighs the observed factors against each other, it cannot be decided which of the factors that may be of more importance than the others. A further difference between the groups is the amount of laboratory work they performed. As described in section 3.1, the students at school B perform lab experiments twice as often as the students from School A visits Chalmers. In conclusion, the test group and the control group showed sufficient similarities before the study in order to further compare them after the project.

5.1.1 Study 1

The results from Study 1 showed no significant increase of interest for chemistry or further education in science among students performing lab experiments at Chalmers compared to other students. There are, however, some results that are interesting to discuss further. Generally, the mean values in both groups decreased from the first to the second survey. A possible cause for the decreasing values may be that the students could be assumed to be more tired of school in April compared to November. This would be indicated by a decrease of interest for all subjects, which is seen in table 4.1. Even if students' general interest for school did decrease, there would be no reason for why the effects on students' interest in science from the visits should not be observable.

Another interesting result is the decrease in students' interest in performing research (question 8). In table 4.3 it is presented that the mean value from school A that visited Chalmers decreased with 0.8 whereas the mean value from school B decreased with 0.5 from the first to the second survey. The significance level presented in table 4.4 is 83.2 percent. That is, it can be stated that the interest of performing research by the students from school A decreased more than the students from school B with an 83.2 percent certainty. Even if the numbers are too low to indicate a significant difference, the results may still be indicators of a trend. The direction of this trend is however unexpected since it would rather be expected that students visiting Chalmers would increase their interest in scientific research. I can think of two possible explanations for this: The first explanation is that when the students from school A visit Chalmers they expect to experience "cool science", which does not occur since the lab situation is similar to a normal secondary school laboratory activity (as it is concluded from Study 2 later in this chapter). Hence, the students get the perception that scientific research is not interesting. The second possible explanation is that the students, while visiting Chalmers, realize the amount of chemical knowledge that is required to perform research and as a consequence lose interest in research. It is such a big gap between the secondary school students' amount of knowledge and their estimation of the required knowledge that it can seem like an impossible task to learn.

There are some weaknesses in the design of the observational study that will have to be discussed. One big difference between the students from school A compared to school B is the amount of laboratory work that were performed in the classes during the observational study. The students from school A visited Chalmers roughly once a month, whereas the students from school B performed lab experiments twice as much in the secondary school laboratory. No previous research regarding how the amount of laboratory experiments affects students' interest for chemistry or science have been found. There is a possibility that the greater number of experiments performed by the students from school B may have increased their interest compared to the students from school A, decreasing the impact of the observational study. Further, the time period over which the study was performed may be an explanation. It could be that students need to visit a university laboratory regularly over a longer period than six months in order for their interest to be affected.

The statistical analysis of the survey results has some weaknesses as well. The difference-in-difference analysis utilized does not consider the individual students' differences in the answers from the first survey to the second. A more complex statistical analysis considering this aspect was not possible to utilize due to the fact that the survey did not include a place for the students to write their names so that the first and the second survey could be paired for each student. The design of the survey was decided upon early in the fall 2018, long before the actual work with this master's thesis had begun. To be able to perform the described study, the first survey had to be performed before the students from school A started to visit Chalmers. Hence, the design of the study was decided on under strong time pressure.

Further, there is a weakness in the difference-in-difference analysis design that may affect the results from the analysis. When performing a difference-in-difference analysis, a parallel increase in both groups is assumed to take place if no exposing of stimuli is added (figure 3.2). Since the two groups from school A and B showed similarities, this assumption was probably correct. If more time would have been available before the project, the parallel increase of interest could have been controlled for by performing two measurements before the visits to Chalmers according to Gertler, Martinez et al. (2016). In that case, the first two measurements would have been used to control if the students' interest increased parallel without a stimulus. Afterwards, a third measurement would have been performed after applying the stimuli (visits to Chalmers) to find the difference-in-difference in the same way as it has been done in this project.

5.1.2 Study 2

Moving on to the observations made in Study 2, there were some differences between the laboratory activities at Chalmers and school B as mentioned above. Teacher A and teacher B showed different strengths and weaknesses as concluded in table 4.5. The prediction was that if more of the observational factors (section 3.3.1) were present during lab experiments, the more the students' learning of and interest for chemistry would increase. The teachers had the same amount of strengths, which could indicate that they impact the students' interest of chemistry to an equal amount. It is also a possibility that different factors affect students' interest unequally. If that is the case, it gets harder to discuss the results from the studies since there are too many independent variables that cooperate in unknown ways. An attempt to try and make sense of the results is however presented later in this section.

The specific strengths of the teachers (presence of factors) were that teacher A made more connections to students' everyday life and was stricter about that students followed the safety rules in the laboratory. Teacher B on the other hand communicated the purpose of the experiment to students more often and also asked more elaborate questions to get the students to reflect upon the chemical phenomena being observed. The laboratory at school B was also more suitable for the experiments being observed than the laboratory at Chalmers. It is interesting that the Chalmers laboratory did not seem suitable for the experiments being performed. At a first thought, a university laboratory should be better equipped and more suitable for a larger amount of lab experiments than a secondary school laboratory. It was among others concluded by Braund and Reiss (2006) (section 2.2) that field trips enables students to experience big science and research. At a second thought however, it is quite logical that the laboratory at school B appeared more suitable for the performed experiments. When previous research states that a university laboratory is more suitable for experiments, it has been in the context of student labs prepared for a specific experiment that utilizes complex analysis equipment that a secondary school would never keep in their laboratory. However, the university visits observed in this project were planned and led by teacher A, who did not spend more time than the students in the Chalmers laboratory. Therefore, the teacher had no specific knowledge of the equipment present in the laboratory and laboratory instructions had to be altered on spot when it appeared that the desired equipment was not available. Further, since nor the teacher or the students from school A spent a big amount of time in the Chalmers laboratory they had to spend quite much time on searching for equipment during the laboratory activities.

Some similarities between teacher A and teacher B were also identified during the direct observations. All of the laboratory instructions handed to the students were of the expository "cookbook" style described by Domin (1999) (section 2.2), even if some of them bordered on discovery style instruction. Another similarity is that both teachers gave the students plenty of time to reflect upon the experiment in the end of the laboratory lesson or stated that they would continue reflections on the next coming chemistry lesson.

An interesting circumstance is that teacher A chose to let the students perform experiments with strong connections to students' day-to-day life in the Chalmers laboratory. During the lab experiments, teacher A also focused on discussing how the experiment was of relevance for everyday life. However, a reaction to this was not seen in the survey results. It could be expected that the students from school A would become more interested in explaining everyday observations with chemistry (as investigated by question 4b) as a result from the efforts from teacher A. The opposite trends were however seen, in table 4.1 it is presented that the difference in mean value among students from school A decreased by 0.3 from the first to the second survey. The mean value among students from school B did on the other hand increase by 0.2 during the same period. The differences presented do however only hold a significance level of 17.3 percent. That means that the trends observed are most probably only a random factor that hold no explanation in students' actual interest for explaining everyday observations with chemistry. Further, it could also be as simple as the observed connections to everyday life from teacher A were just singe observations that are not followed through during other chemistry lessons and experiments, minimizing the impact on students' interest.

From the combined results of Study 1 and Study 2, the importance of the different observational factors for students' interest in chemistry and further education in science can be discussed and research question 3 answered. There was no significant difference between the groups after the observational study and to make sense of the combined results, I can think of three possible explanation models: The first possible explanation is that the strengths showed by teacher B (purpose communication, elaborate questions and suitability of laboratory) promoted the students' interest the most. Since these were present in the control group but not in the test group, it could counteract the increased interest among the students that visited Chalmers and make it appear like there was no difference between the groups after the observational study. The second possible explanation is that the visits to Chalmers do not increase students' interest in chemistry and further education in science. In this case, the results from the two studies indicate that the strengths showed by teacher A (everyday connections and following of rules) affects students' interest just as much as the strengths showed by teacher B (purpose communication, elaborate questions and suitability of laboratory). This would result in no significant differences between the students from school A and school B after the observational study. The third possible explanation is that it would be the styles of laboratory instructions that could increase students' interest for chemistry and further education in science more than the other factors or the visits to Chalmers. During the direct observations, the instruction style being used by the teachers were expository with some influence of discovery instructions in all cases. As presented by Domin (1999) (section 2.2) it has been seen that all other styles than expository style gives the students a better understanding of the experiments, which might transform to a higher interest. Regarding these three possible explanation models, I estimate the first as the most probable because of the following reasons: According to previous research that has shown increase in students' interest for chemistry as a result of visits to student labs (section 2.1.1) it is more likely that there is such an effect and that the Chalmers visits to some degree promote students' interest, than the other way around. Thanks to the supplementary analysis of observations of laboratory classes, I was able to identify a possible factor that might work in the other direction and suppress such an effect: it seems to be the case that the increased interest due to the visits is not larger than the impact from the factors communicating the purpose, asking elaborate question and a suitable laboratory. From the project described in this report a certain answer cannot be drawn, and further research is required to be sure of this prediction.

As briefly mentioned before, there is also a possibility that the results from the direct observations are not valid to reach conclusions of the teachers everyday teaching. It is the everyday teaching that can promote students' interest in chemistry and further education in science more than singe observations. The choice to observe only two lab experiments at Chalmers and school B respectively were made due to time restrictions in the project. It can definitely be concluded that a larger amount of observations would have increased the reliability of Study 2. However, there were some clear trends that were shown in the results from Study

2, and I would argue that it is not a coincidence that these were seen. The experiments in which the direct observations were performed were randomly selected. That indicates that it is the teachers' normal way of acting that has been observed and that the results from Study 2 is valid to represent the teachers' acting in general.

5.1.3 Further discussion

While analyzing the results from Study 1 and Study 2, some aspects appeared interesting even if they are not directly required to answer the research questions for the project. During the project, some possible improvements of the visits to Chalmers that may increase the effects on students' interest in chemistry and further education in science was identified. As mentioned before, teacher A showed strengths (connections to everyday life, following of safety rules and reflection time) that can increase students' interest in chemistry. There were, however, some observational factors that were not present during the laboratory activities at Chalmers (other instruction style than expository, purpose communication, elaborate questions and suitability of laboratory). If these non-present factors are improved, it would probably promote the students' interest. This is however a general improvement that does not specifically consider the visits to a university laboratory. Further, there are some alterations that could be implemented in the Chalmers laboratory that may increase the value of the visits to students' interest. First, I think there is a possibility to increase the impact on students' interest by taking advantages of the possibilities present in a university laboratory to perform more complex experiments with the equipment at hand. It was discussed by Braund and Reiss (2006) and Glowinski and Bayrhuber (2011) (section 2.1.1) that better-equipped laboratories is one of the many positive possibilities of student labs. Secondly, the other large advantage at Chalmers is the access to possible role models. An opportunity of improvement of the visits could be to include for students to meet researches, employees and students from Chalmers. This could be integrated either by role models being present during the lab experiments, as meet-ups after the performed experiments or as mentorship programmes. As it was concluded by Gibson and Ogbu (1991) and Zirkel (2002) (section 2.1.2) having a role model of the same ethnicity and gender strongly affects the career goals of students. Further, the role model aspect of the visits could also be stretched to include for students to get more chances to experience how it is to study at a university, perhaps in the form of campus-tours.

Another aspect of the laboratory activities at Chalmers that is of interest to discuss is the "culture of power" explained by Barton and Yang (2000) (section 2.1.2). As described in section 4.2, it could be observed during the visits to Chalmers that much of the efforts of teacher A during the experiments focused on students getting a "right answer". It was described by Barton and Yang (2000) that the portrayal of science subjects as absolute and with absolute answers generates a picture of science as a subject for very smart people. When this happens, it would reasonably result in a decrease of students' interest in chemistry and further education in science. In order to affect students' interest in a positive way, teachers could therefore have in mind how the students' perception of the subject is affected by his or her acting.

From the results of the project, it can also be discussed where the recourses from a school can be best utilized. The results show that the visits to Chalmers laboratories in the shape they are today does not promote students' interest in chemistry and further education more than strengths in the everyday teaching can do. Consequently, there is no apparent reason for schools to invest in visits to a university laboratory on a regular basis if they are performed in the investigated way. There could however still be of value for schools to put recourses at university visits, if they are further developed according to the suggestions above. It is my belief that visits to a university on a regular basis on some level is favorable for students' interest in science even if this study could not identify how.

5.2 Conclusions

According to the discussions presented in section 5.1, answers to the research questions for the project have been concluded and are described below. As discussed, there are factors that may affect the conclusions drawn and further research would be interesting to perform to further investigate the impact on students' interest from long-term university visits.

Do regular visits to a university laboratory generally affect secondary school students' attitudes towards chemistry compared to students performing lab experiments in their regular school laboratory?
No significant differences in students' interest in chemistry or further education in science due to visits to a university laboratory on a regular basis could be observed in the project. There are however some weaknesses in the design of the study that may indicate that students' interest could be promoted due to the visits.

How does the lab situation performed at Chalmers differ to the lab situation at a laboratory located in an upper secondary school in regard of the design of lab experiments and the teachers' acting?
There were no differences in the design of lab experiments when comparing the experiments at Chalmers and the experiment at school B. The observed differences included that the laboratory at Chalmers seemed less suitable for the observed experiments than the laboratory at school B. Further, some differences in the teachers' acting were observed. Teacher A made more connections to students' everyday life and were stricter with the safety rules of the laboratory whereas teacher B did communicate the purpose of experiments to a higher degree and gave the students more elaborate questions. A similarity between the teachers was that both of them gave the students time to reflect upon the experiments at the end of the laboratory lesson or in the next chemistry lesson.

Can the observations help to make sense of the results from question 1, and if so how?
The observations from Study 2 can to some extent help to understand the survey results from Study 1. There are three possible explanation models of how the results from the studies connect to each other. The most likely explanation is that the visits to a university laboratory on a regular basis to some extent promotes students' interest in chemistry and further education in science. However, in this study this increase in interest was neutralized by the strengths shown by teacher B in the teaching of the control group. Further research is required to verify this conclusion.

5.3 Further research

After the project, there are still questions that would be interesting to investigate. Further research may be performed to achieve more knowledge of how visits to a university laboratory can affect students' interest in chemistry and further education in science. Firstly, the same study as performed in this project may be performed again on better premises. It would be interesting to perform an experiment, with a uniform student group from one school that are randomly divided in an experiment group going to Chalmers and a control group performing lab experiments at the school. In a controlled experiment, impact from factors such as different teachers, different experiments and different amounts of laboratory activities would be controlled for. Further, by designing the survey in a way that allows for the statistical analysis to account for individual differences the study could be more reliable.

Secondly, it would be interesting to investigate the effects of visits to Chalmers on students' interest in a longer time-frame than for this study. It may be that the period that this study stretched over (six months) was not long enough for an increased interest to give effect. In a study over a longer period of time, it could be investigated whether a longer collaboration between the school and the university has to take place to promote students' interest.

A third proposal for further research would be to perform studies on students from other socioeconomic backgrounds than the students participating in this project. It is feasibly to assume that students from other types of families could be affected differently from the same type of university visits. Further, investigations regarding if boys and girls are affected differently from the visits would also be interesting.

References

Agerberg, M. (2019). Personal communication, University of Gothenburg, Department of Political Science.

Barton, A. C. and K. Yang (2000). "The culture of power and science education: Learning from Miguel." Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching 37(8): 871-889.

Berry, A., et al. (1999). "Helping students learn from laboratory work." Australian Science Teachers' Journal 45(1): 27-31.

Braund, M. and M. Reiss (2006). "Towards a more authentic science curriculum: The contribution of out-of-school learning." International Journal of Science Education 28(12): 1373-1388.

Broman, K., et al. (2011). "Chemistry in crisis? Perspectives on teaching and learning chemistry in Swedish upper secondary schools."

Buck, G. A., et al. (2002). "Bringing female scientists into the elementary classroom: Confronting the strength of elementary students' stereotypical images of scientists." Journal of Elementary Science Education 14(2): 1.

Dabney, K. P., et al. (2012). "Out-of-school time science activities and their association with career interest in STEM." International Journal of Science Education, Part B 2(1): 63-79.

DeWitt, J. and J. Hohenstein (2010). "School trips and classroom lessons: An investigation into teacher–student talk in two settings." Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching 47(4): 454-473.

DeWitt, J. and J. Osborne (2007). "Supporting teachers on science-focused school trips: Towards an integrated framework of theory and practice." International Journal of Science Education 29(6): 685-710.

DeWitt, J. and M. Storksdieck (2008). "A short review of school field trips: Key findings from the past and implications for the future." Visitor studies 11(2): 181-197.

Domin, D. S. (1999). "A review of laboratory instruction styles." Journal of chemical education 76(4): 543.

Donnelly, J. F. (1998). "The place of the laboratory in secondary science teaching." International Journal of Science Education 20(5): 585-596.

Eriksson-Zetterquist, U., et al. (2015). Organisation och organisering. Stockholm, Liber AB.

Esaiasson, P., et al. (2017). Metodpraktikan. Konsten att studera samhälle, individ och marknad. Stockholm, Wolters Kluwer.

Fisher, D., et al. (1998). "Laboratory learning environments and practical tasks in senior secondary science classes." Research in Science Education 28(3): 353-363.

Fraser, B. J., et al. (1993). "Development and cross-national validation of a laboratory classroom environment instrument for senior high school science." Science Education 77(1): 1-24.

Gertler, P. J., et al. (2016). Impact Evaluation in Practice. Washington DC, International Bank for Reconstruction and Development.

Gibson, M. A. and J. U. Ogbu (1991). Minority status and schooling: A comparative study of immigrant and involuntary minorities, ERIC.

Glowinski, I. and H. Bayrhuber (2011). "Student Labs on a University Campus as a Type of Out-of-School Learning Environment: Assessing the Potential to Promote Students' Interest in Science." International Journal of Environmental and Science Education 6(4): 371-392.

Gothenburg Region (2015). "Slutantagningen 2015 Antagningspoäng och medelvärde." Retrieved 2019-02-25, from https://www.goteborgsregionen.se/download/18.4e85091914e1a80913db14da/1435134217001/2015%20Antagningspoäng%20och%20medelvärde.pdf.

Gothenburg Region (2016). "Slutantagningen 2016 Antagningspoäng och medelvärde." Retrieved 2019-02-25, from https://www.goteborgsregionen.se/download/18.34f679301559581d8e7d731/1467114678892/2016%20Antagningspoäng%20och%20medelvärde.pdf.

Gothenburg Region (2017). "Slutantagningen 2017 Antagningspoäng och medelvärde." Retrieved 2019-02-25, from https://www.goteborgsregionen.se/download/18.3a8095f615ce16a2281cda59/1498648448971/2017%20Antagningspoäng%20och%20medelvärde.pdf.

Gunnarson, P. (2009). "Gymnasieelevers inställning till svensk forskning." Ungdomsbarometern. Kvalitativ onlineenkät.

Hofstein, A. and V. N. Lunetta (1982). "The role of the laboratory in science teaching: Neglected aspects of research." Review of educational research 52(2): 201-217.

Högström, P., et al. (2010). "Lab work and learning in secondary school chemistry: The importance of teacher and student interaction." Research in Science Education 40(4): 505-523.

Itzek-Greulich, H., et al. (2014). The impact of a science center outreach lab workshop on German 9th graders' achievement in science. 10th Conference of the European Science Education Research Association, Proceedings.

Itzek-Greulich, H., et al. (2015). "Effects of a science center outreach lab on school students' achievement–Are student lab visits needed when they teach what students can learn at school?" Learning and Instruction 38: 43-52.

Luehmann, A. L. (2009). "Students' perspectives of a science enrichment programme: Out-of-school inquiry as access." International Journal of Science Education 31(13): 1831-1855.

Luehmann, A. L. and D. Markowitz (2007). "Science Teachers' Perceived Benefits of an Out-of-school Enrichment Programme: Identity needs and university affordances." International Journal of Science Education 29(9): 1133-1161.

Millar, R. (2004). "The role of practical work in the teaching and learning of science." High school science laboratories: Role and vision: 1-24.

National Agency for Higher Education (2003). Utvärdering av utbildningar i kemi vid svenska universitet och högskolor. Stockholm.

O'Reilly, K. (2009). Key Concepts in Ethnography. Los Angeles, Sage Publications.

Rice, J. A. (2007). Mathematical Statistics and Data Analysis. Belmont, Brooks/Cole.

Savenye, W. C. (1990). "Role models and student attitudes toward nontraditional careers." Educational Technology Research and Development 38(3): 5-13.

Sjøberg, S. (2010). Naturvetenskap som allmänbildning - en kristisk ämnesdidaktik. Lund, Studentlitteratur.

Statistics Sweden (2019). "Sveriges export." Retrieved 2019-04-02, from https://www.scb.se/hitta-statistik/sverige-i-siffror/samhallets-ekonomi/sveriges-export/.

Swedish Council for Higher Education (2017). Utbildning går i arv. Stockholm, Universitets- och högskolerådet.

Swedish Higher Education Authority (2019). "Antal helårsstudenter inom kemi." Retrieved 2019-03-13, from https://www.uka.se/statistik--analys/statistikdatabas-hogskolan-i-siffror/statistikomrade.html?statq=https%3A%2F%2Fstatistik-api.uka.se%2Fapi%2Ftotals%2F34%3Funiversity%3D1%26year%3D2017%252F18%26group_slug%3D7481a7f457b5335f0a7f108fffcd58305e728de3.

Swedish Public Employment Service (2019). Var finns jobben? Bedömning för 2019 och på fem års sikt. Stockholm, Arbetsförmedlingen.

Widigson, M. (2018). Personal communication, Center for School Development Gothenburg.

Zirkel, S. (2002). "Is there a place for me? Role models and academic identity among white students and students of color." Teachers College Record 104(2): 357-376.

A Appendixes

A.1 Student survey

A.1.1 Swedish version

Hej, den här enkäten innehåller frågor om hur du ser på skolan ur olika aspekter och särskilt kemi. Jag som har delat ut den heter Sara Juul och jag vill använda svaren i mitt examensarbete som handlar om gymnasieelevers intresse för naturvetenskap och vad man planerar att göra efter studenten. Du kommer att vara anonym i dina svar, dvs. ingen kommer att få veta vilka svar just du angett. När rapporten är klar kommer jag att skicka den till din lärare som kan berätta om resultaten. Enkäten innehåller 13 frågor.

1. Vissa ungdomar tycker att det är roligt att gå i skolan och andra inte. Hur roligt tycker du det är att gå i skolan?

1	2	3	4	5	Vet ej
Inte alls roligt	Knappast roligt	Varken roligt eller inte roligt	Roligt	Mycket roligt	

2. Om du tänker på just det som händer på lektionerna i skolan, hur rolig tycker du att den delen av skolan är?

1	2	3	4	5	Vet ej
Inte alls roligt	Knappast roligt	Varken roligt eller inte roligt	Roligt	Mycket roligt	

3. Många elever är mer intresserade av vissa skolämnen än vad de är av andra. Hur intresserad är du av följande ämnen?

Matematik

1	2	3	4	5	Vet ej
Inte alls Intresserad	Knappast intresserad	Varken intresserad eller inte intresserad	Intresserad	Mycket intresserad	

Engelska

1	2	3	4	5	Vet ej
Inte alls Intresserad	Knappast intresserad	Varken intresserad eller inte intresserad	Intresserad	Mycket intresserad	

Historia

1	2	3	4	5	Vet ej
Inte alls Intresserad	Knappast intresserad	Varken intresserad eller inte intresserad	Intresserad	Mycket intresserad	

Naturvetenskap

1	2	3	4	5	Vet ej
Inte alls Intresserad	Knappast intresserad	Varken intresserad eller inte intresserad	Intresserad	Mycket intresserad	

Idrott

1	2	3	4	5	Vet ej
Inte alls Intresserad	Knappast intresserad	Varken intresserad eller inte intresserad	Intresserad	Mycket intresserad	

4. Nedan följer några frågor speciellt om kemi. Kemiämnet består av flera olika delar. En del tycker att vissa delar är intressantare än andra. Markera hur intressanta du tycker att de olika delarna inom kemiämnet är?

Laborationer på kemin

1	2	3	4	5	Vet ej
Inte alls Intresserad	Knappast intresserad	Varken intresserad eller inte intresserad	Intresserad	Mycket intresserad	

Teoretiska kemikunskaper

1	2	3	4	5	Vet ej
Inte alls Intresserad	Knappast intresserad	Varken intresserad eller inte intresserad	Intresserad	Mycket intresserad	

Kunskap om vad som driver olika kemiska fenomen

1	2	3	4	5	Vet ej
Inte alls Intresserad	Knappast intresserad	Varken intresserad eller inte intresserad	Intresserad	Mycket intresserad	

Att med kemisk kunskap förklara saker vi kan se i vardagen

1	2	3	4	5	Vet ej
Inte alls Intresserad	Knappast intresserad	Varken intresserad eller inte intresserad	Intresserad	Mycket intresserad	

5. Tycker du att det är viktigt att lära sig om kemi och varför i så fall?

____

____

____

6. Ibland har man en idé om vad man skulle vilja göra efter skolan redan när man går på gymnasiet. Hur tänker du själv om de följande alternativen?

Jag skulle vilja jobba direkt

1	2	3	4	5	Vet ej
Inte alls troligt	Knappast troligt	Varken troligt eller inte troligt	Troligt	Mycket troligt	

Jag skulle vilja studera vidare på högskola/universitet

1	2	3	4	5	Vet ej
Inte alls troligt	Knappast troligt	Varken troligt eller inte troligt	Troligt	Mycket troligt	

7. Om du tänker att du vill studera vidare, direkt efter gymnasiet eller senare, vilken ämnesinriktning tror du i så fall att du skulle välja? Rangordna de alternativ du helst skulle vilja studera vidare inom med siffrorna 1–5 eller 1–6 om du skriver in ett eget alternativ. 1 betyder att du helst vill studera vidare inom den inriktningen.

Naturvetenskaplig inriktning

Vård/medicininriktning

Samhällsinriktning

Humanistiska ämnen

Ekonomisk inriktning

Annat, nämligen:

8. Efter att ha studerat på högskola/universitet kan man bli forskare inom alla möjliga ämnen. Tror du att det är troligt att du själv skulle vilja forska någon gång i framtiden?

1	2	3	4	5	Vet ej
Inte alls troligt	Knappast troligt	Varken troligt eller inte troligt	Troligt	Mycket troligt	

9. Vad tror du att en forskare inom kemi gör?

____

____

____

10. Nedan följer namnen på några kända kemister. Kanske känner du igen någon av dem? De är alla kända för att ha gjort viktiga kemiska upptäckter. Försök para ihop namnen med den upptäckt som personen är känd för. Dra alltså ett sträck mellan namn och upptäckt.

Marie Curie	Upptäckten av dynamiten
Alfred Nobel	Upptäckten av grundämnet radium
Rosalind Franklin	Utformandet av periodiska systemet
Niels Bohr	Upptäckter inom reaktionsmekanismer
Dmitrij Mendelejev	Utformandet av en atommodell
Lise Meitner	Upptäckten av kärnklyvning
Ahmed Zewail	Upptäckter inom riktad evolution av enzymer
Frances Arnold	Upptäckter om DNA-molekylens uppbyggnad

Avslutningsvis skulle jag vilja fråga dig lite om din bakgrund, både om din egen bakgrund och din familjs bakgrund.

11. Vilken kön har du?

Tjej Kille Annat Vill inte uppge

12. Vad arbetar dina föräldrar med?

Mamma:

Pappa:

13. Vilken utbildning har dina föräldrar?

Mamma

Grundskola Gymnasium Högskola/universitet Vet inte

Pappa

Grundskola Gymnasium Högskola/universitet Vet inte

Jag kan tänka mig att svara på fler frågor under en intervju: Ja Nej

Om ja, fyll i kontaktuppgifter nedan.

Namn:

Email:

Telefonnummer:

A.1.2 English version

Hello, this survey has questions about your view of school in general and of chemistry in particular. My name is Sara Juul and I would like to use the answers of the survey in my master thesis that investigates secondary school students' interest in science and plans for the future. Your answers will be anonymous, that is, no one will be able to know what you specifically answered in the survey. When the report is finished, I will send it to your teacher so he or she can tell you about the results. The survey consists of 13 questions.

1. Some students enjoy going to school and others not so much. How much do you enjoy going to school?

1	2	3	4	5	Don't know
Not enjoyable at all	Barely enjoyable	Neither enjoyable or not enjoyable	Enjoyable	Very enjoyable	

2. If you think about what happens on the lessons in school in particular, how much do you enjoy that part of school?

1	2	3	4	5	Don't know
Not enjoyable at all	Barely enjoyable	Neither enjoyable or not enjoyable	Enjoyable	Very enjoyable	

3. Several students are more interested in certain subjects than others. How interested are you in the following subjects?

Mathematics

1	2	3	4	5	Don't know
Not interested at all	Barely interested	Neither interested or not interested	Interested	Very interested	

English

1	2	3	4	5	Don't know
Not interested at all	Barely interested	Neither interested or not interested	Interested	Very interested	

History

1	2	3	4	5	Don't know
Not interested at all	Barely interested	Neither interested or not interested	Interested	Very interested	

Science

1	2	3	4	5	Don't know
Not interested at all	Barely interested	Neither interested or not interested	Interested	Very interested	

Health class

1	2	3	4	5	Don't know
Not interested at all	Barely interested	Neither interested or not interested	Interested	Very interested	

4. Below is some questions specifically about chemistry. Chemistry as a school subject consists of several parts. Some people find certain parts more interesting than others. Mark how interesting you find the different parts of chemistry.

Lab experiments in chemistry

1	2	3	4	5	Don't know
Not interested at all	Barely interested	Neither interested or not interested	Interested	Very interested	

Theoretical chemistry knowledge

1	2	3	4	5	Don't know
Not interested at all	Barely interested	Neither interested or not interested	Interested	Very interested	

Knowledge of what drives different chemical phenomena

1	2	3	4	5	Don't know
Not interested at all	Barely interested	Neither interested or not interested	Interested	Very interested	

To explain observations in everyday life with chemical knowledge

1	2	3	4	5	Don't know
Not interested at all	Barely interested	Neither interested or not interested	Interested	Very interested	

5. Do you think it's important to learn about chemistry and in that case why?

____

____

____

6. Sometimes people have an idea of what they want to do after school when they're in secondary school. What do you think about the following alternatives?

I would like to work directly after school

1	2	3	4	5	Don't know
Not likely at all	Barely likely	Neither likely or not likely	Likely	Very likely	

I would like to study at a university

1	2	3	4	5	Don't know
Not likely at all	Barely likely	Neither likely or not likely	Likely	Very likely	

7. If you would like to study at a university, directly or later in life, what major field of study do you think you would choose? Rank the alternatives you'd preferably major in with the numbers 1-5 or 1-6 if you add an own alternative. 1 means you'd like to major in that subject most.

Science

Healthcare/medicine

Social science

Humanities

Economics

Other, namely:

8. After a college degree there's a possibility to become a researcher in any subject. Do you think that you'd like to perform research sometime in the future?

1	2	3	4	5	Don't know
Not likely at all	Barely likely	Neither likely or not likely	Likely	Very likely	

9. What do you think a researcher in chemistry does?

10. Below are the names of some famous chemists. Maybe you recognize some of them? They are all known for important chemical discoveries. Try to pair the names with the discovery that person is known for. Draw a line between name and discovery.

Marie Curie	The discovery of dynamite
Alfred Nobel	The discovery of radium
Rosalind Franklin	The design of the Periodic Table of Elements
Niels Bohr	Discoveries within reaction mechanisms
Dmitrij Mendelejev	The design of an atomic model
Lise Meitner	The discovery of nuclear fission
Ahmed Zewail	Discoveries within directed evolution of enzymes
Frances Arnold	Discoveries of the DNA-molecule's construction

Lastly, I would like to ask some questions about your background, both your own and your parents'.

11. Which gender do you have?

Female Male Other Don't want to state

12. What do your parents work with?

Mother:

Father:

13. What academic degrees does your parents have?

Mother

Middle school Secondary school University Don't know

Father

Middle school Secondary school University Don't know

I could answer more questions during an interview: Yes No

If yes, fill in contact information below.

Name:

Email:

Phone number:

A.2 Open survey questions

A.2.1 Do you think it is important to learn chemistry? In that case, why?

The students' answers from the question "Do you think it is important to learn chemistry? In that case, why?" are presented in table A.1 below.

Survey 1	
School A	**School B**
Yes, it is important since chemistry includes much about medicine and how they were invented, which I think is important for humanity. It is important since it is good to know how things are structured. I think it is delightful to know more about substances and things we use and are surrounded by every day. For example, to know what CO_2 is. Yes, since chemistry helps us understand things in our everyday life. Chemistry is important since it is present everywhere and to understand the basics of life. Yes absolutely, there are harmful substances that may harm us. For example, radioactive substances that cause cancer and harm the nature. It is good to know if substances we are using are harmful or not. I like chemistry and enjoy learning more than I do right now. It is fun to learn chemistry, there are many things we need to learn that are related to chemistry. It is important to learn chemistry if you need it in your everyday life or to graduate. Of course, it is important since we need new medicines and it is chemists that invent those. We can understand the world better with chemical knowledge. For example, global warming. Yes, since chemistry is something we use in our everyday life. Chemical knowledge gives	Maybe it is important for students that are more science orientated than I am. It is educational and good to know chemistry. I think it is important only if you need the knowledge in a future career. It is important in chemical knowledge explains how the elements form chemical substances. It is important since we need to learn of different phenomena happening. It is important to get extra credits for further education. It can be important to give an understanding of how things function. It is important to give an understanding of chemical reactions and what may happen if different substances are mixed. Yes, it is important for science majors. It is good to learn new things, understand substances and try new things. It is important to learn since chemical knowledge teaches us how the world is constructed. For me, it is important to learn theoretical and experimental skills in chemistry. It is important to learn how chemical substances and the world is constructed. I have always loved chemistry and enjoy explaining things I see with chemical knowledge.

<table>
<tr><td>an understanding of materials and substances that forms in chemical reactions.

It depends upon what you want to do after secondary school.

It is important to learn chemistry since it develops medicines and other healthcare.

It is important, especially if you want to work with chemistry or study it further in university. Chemistry helps us understand certain things in the world.

It is important to be able to see how everything affects us.

Yes, I think so, it is always good with knowledge since you may need it in the future.

If you want to participate in further education, you need chemical knowledge.

Chemical knowledge can be required in a future work, for example if you become a doctor.

I think chemical knowledge is important when developing new medicines.

I think it is important to learn chemistry since it is an important subject.

Chemistry is important, especially for me that want to become a doctor.

It is important to learn chemistry if you need in the future, for example if you become a chemistry teacher.

It is important to get an understanding of how things are structured and connected.</td><td></td></tr>
<tr><td colspan="2" align="center">Survey 2</td></tr>
<tr><th>School A</th><th>School B</th></tr>
<tr><td>The chemical knowledge I have achieved has helped me to better understand experiments, cooking and other interests.

It is important to distinguish harmful substances from non-harmful.

I think it is important to learn since I am interested in how harmful substances affects our environment.

It is important since chemical knowledge can explain how things work in a detailed manner.</td><td>It is important since you may need the knowledge in the future.

No, I do not think I will need chemical knowledge.

It is important since it teaches us how everything interacts chemically around us.

It is important to learn about everything around us, for example, salts and atoms.

For me it is important since I want to become a dentist and need a grade in chemistry 2.</td></tr>
</table>

It is important since we need new medicines. No, it is not important. Yes, it is important to learn how our environment functions. It is important to learn chemistry if you want to participate in further education, it can also be important to help us in our everyday life. It can be important if you want to get a logic explanation of how things function. Yes, I think it is important. It is important if you need it for your further education. It is important since everything is constructed of atoms and it is important to know how your surrounding function. I think chemical knowledge is important since it helps me understand things. It is important to learn how things are structured.	I think chemistry is interesting since we get to explain things we see in everyday life. I do not think it is important to learn. I do not think it is important to learn since not everyone will work with developing new medicines in the future. Yes, it is important knowledge to have. It is important to observe and understand things we see in everyday life. To know about substances that we use. It is important since it gives us a better understanding of why some things happens. No, it is not important. It is important to know how the world is constructed and it is important in new research. I think it is important since I want to become a dentist. Also, I find it interesting. It is important since you might need it in the future. It is important if you want to become a chemist. It is also good to for example know why water boils or melts. I do not think it is important, but quite interesting to know about chemical substances.

Table A.1: Answers from the open question regarding if students find it important to learn chemistry.

A.2.2 What do you think a researcher in chemistry does?

The students' answers from the question "What do you think a researcher in chemistry does?" are presented in table A.2 below.

Survey 1	
School A	**School B**
Researches different substances, how to create new substances and isotopes. Researcher within the chemistry field. Does observations. I don't know. Finds new chemical substances. They have much knowledge and performs experiments.	Researches substances characteristics. I don't know. Researches. I don't know. Participates in further education within chemistry. Discovers new things.

They do different things related to chemistry, for example chemical history. They invent new things they society might need now or in the future. They find undiscovered things. Develops new medicines. Researches and finds chemical substances and performs experiments. Develop medicines. Researches new medicines. They find and learn how the chemistry works. For example, finds new medicines. Researches the elements and finds facts. They find new elements and researches chemical substances. I don't know. They find chemical substances.	Experiments and explores chemistry. They think a lot and have learnt much about chemistry. Writes hypotheses, tries them to get a result. Researches chemical phenomena. They test why things work as they do. Performs experiments on chemical substances to learn their characteristics. Try to find new substances that may be more efficient or environmentally friendly. Experiments and finds explanations that we can't explain scientifically. Researches the elements, mixes chemicals to see if they get a result. Learn more within different chemical fields and studies at a higher level. Searches for new elements and explores their characteristics. Researches chemical substances. Researches theories. For example, string theory in physics. Researches phenomena, elements in the nature.
Survey 2	
School A	**School B**
They research chemical phenomena. Make bombs. Researches. Don't know. Researches new substances and methods invents new stuff. Researches the earth and finds new substances. Finds new substances. They try to learn how medicines and chemicals can be used in a more efficient way. Mostly finds new substances. I don't know. Researches within chemistry and experiments.	Researches what can be created from different substances. Researches in broad fields, for example water acidification or energy sources. Performs experiments on chemical substances. Experiments. Finds chemicals use for the society. Finds new substances. Finds new shortcuts for chemical calculations. There are researchers in different fields. Researches. Develops new medicines. Thinks. Researches.

Experiments and research in different fields.	Performs experiments and explores things.
Researches new substances found in the earth, and medicines.	Sees things in the everyday life and problems we have today.
I don't know.	Finds new substances.
Invents things depending on chemistry, new substances for example.	Researches chemical phenomena to develop things that may increase the quality of life.
Researches try to understand chemical phenomena. For example, quantum physics and atoms. They mix reactants to achieve products.	Finds new things and easier methods to achieve results.
	Researches medicines and atoms.
	Researches different substances.

Table A.2: Answers from the open question regarding what students think a chemical researcher does.

A.3 Laboratory instructions

Below are English versions of the laboratory instructions handed to students from school A and B for the experiments performed during the observations of the study. When the experiments were performed, and by which students are presented below.

A.3.1	Search for protein	School A	March 11th, 2019
A.3.2	Identification of an organic substance	School B	March 11th, 2019
A.3.3	Enzyme activity	School B	April 1st, 2019
A.3.4	Decomposition of bicarbonate	School A	April 8th, 2019

A.3.1 Search for protein

This experiment shows how you can prove protein by use of solutions of sodium hydroxide and copper sulfate. The experiment is called Biuret test.

You will need
NaOH solution (roughly 2 moles/dm^3)
CUSO$_4$ solution (roughly 0,5 moles/dm^3)
Albumin
Wet peas
Other food groceries (for example flour, rice and milk)
Spatula
Test tube
Small beaker
Measuring cylinder
Mortar and pestle

Create a protein solution by mixing a spatula of albumin (dried egg white) in 25 cm^3 water.

Pour some of the protein solution in a test tube. Add roughly 10 drops of NaOH solution and some drops of CuSO$_4$ solution. Shake the test tube so the solutions are mixed.

The color of the solution indicates that it contains protein. What is the color?

Grind the wet peas with the mortar with some water. Pour the mixture (you will might need to filter the mixture to remove the roughest particles) in a test tube and perform the Biuret test. Do peas contain protein?

Test other groceries in a similar way as the peas and decide which ones contains protein.

A.3.2 Identification of an organic substance

You can identify a substance on its characteristics. Some characteristics, for example smell and color, are difficult to describe with words. It is therefore best to use characteristics that can be measured. Quantitative measurements can for example be density, boiling point and melting point.

You will receive a test tube from your teacher containing a liquid. The liquid is one of the substances in the table below. You will, through experimentations, measure the substance's density and boiling point, as well as investigate the substance's solubility in water and heptane. By comparing your results with corresponding data in the table below to determine what substance your liquid is.

Substance	Solubility in water	Solubility in heptane	Density (g/cm^3)	Boiling point (°C)
1-propanole	+	+	0,80	97
Acetone	+	+	0,79	56
Cyclohexane	-	+	0,78	81
Ethanol	+	+	0,79	79
Ethyl acetate	-	+	0,90	77
Methanol	+	-	0,80	65
n-Heptane	-	+	0,68	98

Density

The density ρ is calculated by $\rho = \frac{m}{V}$ where m is the mass and V is the volume. Weigh a 10 ml measuring cylinder and note the mass. Pour your liquid in the cylinder and weigh again, note the mass. Now you have the information you need to calculate the density of your liquid.

Mass, measuring cylinder + liquid	g
Mass, empty measuring cylinder	g
Liquid mass (m)	g
Liquid volume (V)	cm^3
Liquid density (ρ)	g/cm^3

Boiling point

Put together the equipment for measurement of the boiling point as in the picture. Pour roughly 5 ml of the unknown liquid in the test tube. Put a boiling stone in the tube (prevents big bubbles when boiling). Alter the thermometer so the ball is roughly 1 cm above the liquid. Fill half of the beaker with water. Heat the water until the liquid in the test tube starts to boil. Read the thermometer when the temperature is stable.

Solubility

You need to empty test tubes. Pour 2 cm of water in one of the tubes, and 2 cm of heptane in the other. Pour as much volume of the unknown liquid in each of the tubes. Close the tubes with a cork and shake vigorously so the contains is mixed. Let the test tubes stand for a couple of minutes and observe what is happening. If a liquid solves in another liquid the is no separate layers formed. Write the results in the compilation.

Compilation of results

Density	
Boiling point	
Solubility in water	
Solubility in heptane	

Risk assessment

All substances are flammable, and you have to be careful when deciding the boiling point. Fumes from substances should not be inhaled. The experiment should therefore be performed in a fume cabinet. Rests from the experiment should be collected in a special vessel and cannot be poured in the sink.

A.3.3 Enzyme analysis

In this experiment you will examine the enzyme katalas and how the enzyme activity is affected by the substrate concentration. Katalas is an enzyme that catalyzes the degradation reaction of hydrogen peroxide (the substrate): $2\ H_2O_2 \rightarrow 2\ H_2O + O_2$

Hydrogen peroxide is normally produced in all cells but is harmful, katalas has therefore an important, protecting role. You can read more of katalas at the "Molecule of the Month"-page you looked at in the computer task, here: http://pdb101.rcsb.org/motm/57

Katalas exists in many different organisms, and in different parts of their cells. It exists for example in yeast cells. In today's experiment, we will use yeast instead of pure protein.

<u>Risk assessment</u>
Use safety googles and robes.
Hydrogen peroxide is corrosive and oxidizing and a bleach, be careful with the handling of it.
All substances can be poured in the sink after the experiment.

<u>Chemicals</u>
Hydrogen peroxide (3%)
Water
Suspension of yeast

<u>Implementation</u>

1. Produce a dilution series for the hydrogen peroxide solution with 3%, 1,5%, 0,75%, 0,375% and 0% (you will need roughly 100 ml of each solution) and pour roughly the same amount of each solution in 5 test tubes or beakers.
    a. To do 1,5% H_2O_2-solution, take 100 ml of 3% H_2O_2 and mix with 100 ml H_2O.
    b. To do 0,75% H_2O_2-solution, take 100 ml of 1,5% H_2O_2 and mix with 100 ml H_2O.
    c. And so on.
2. Cut out 20 pieces of filtration paper with the same area and shape.
3. Now you are ready for the actual activity measurement. You will perform three measurements for each concentration of hydrogen peroxide. Note the time in table for each experiment.

Concentration H_2O_2	Time 1	Time 2	Time 3
3 %			
1,5 %			
0,75 %			
0,375 %			
0 %			

4. Shake the yeast solution carefully to make sure the yeast is equally dissolved (it will sink to the bottom if it is left alone).
5. Take one piece of filtration paper with a pair of tweezers and dip in the yeast solution for 5 seconds.

6. Let the piece dry on a filtration paper for 30 seconds.
7. Drop the piece of filtrations paper in the test tube containing the concentration you shall measure with the tweezers.
8. Start the timer when the filtration paper meets the surface of the solution and measure the time it takes for the piece to float back up to the surface. Note the time in the table (seconds and hundreds of seconds), lift the piece with the tweezers, throw it away and restart from number 4.
9. Perform the experiment 3 times for each tube/beaker with hydrogen peroxide.

Questions and tasks

1. Write your data in a diagram with the time (in seconds) as a function of the substrate concentration (% H_2O_2).
2. Try to draw a trend line, how does it look?
3. When interpreting data, it is favorable with linear connections. Can you recompile your data, so you achieve a linear connection? It may be easier if you look at question 4 in the same time.
4. How is the measured time related to the enzyme activity?
5. Recalculate the times to enzyme activity and note in the table. Calculate mean value and standard deviation (SD).

Conc. H_2O_2	**Activity 1**	**Activity 2**	**Activity 3**	**Mean**	**SD**
3 %					
1,5 %					
0,75 %					
0,375 %					
0 %					

6. Draw the activity (mean) as a function of the concentration of hydrogen peroxide.
7. What does the diagram say of the enzyme activity's dependent of the concentration of hydrogen peroxide?
8. Is the result what you expected?
9. What do you think will happen if you increase the substrate concentrate further?
10. What will happen if you decrease or increase the enzyme concentration?

A.3.4 Decomposition of bicarbonate

Bicarbonate is the everyday-name for sodium bicarbonate, $NaHCO_3$. This salt decomposes when heated. During the reaction a gas and a solid product is formed. It is the gas generation is utilized when bicarbonate is used in baking. The gas makes the dough porous. It is possible to imagine that one of the three following reaction formulas describes what is happening when sodium bicarbonate is heated. When heating the sodium bicarbonate, the temperature in the salt should be between 160 and 180°C (it should not exceed 180°C).

1. $2\ NaHCO_3\ (s) \rightarrow Na_2O\ (s) + 2\ CO_2\ (g) + H_2O\ (g)$
2. $2\ NaHCO_3\ (s) \rightarrow Na_2CO_3\ (s) + CO_2\ (g) + H_2O\ (g)$
3. $NaHCO_3\ (s) \rightarrow NaOH\ (s) + CO_2\ (g)$

Which of these reaction formulas describes what happens when sodium bicarbonate is heated?

You will need
Sodium bicarbonate
Scale
Big test tube that is heat resistant
Thermometer (0-250°C)
Spatula
Stative with clamp and muff
Bunsen burner

Suggestion of execution

- Weigh a dry test tube. Transfer bicarbonate to the tube (4-5 g should be enough) and weigh again. Calculate the mass of salt in the tube.
- Attach the test tube at a stative and put the thermometer in the salt. Thereafter, heat the test tube carefully so the temperature in the salt is between 160 and 180°C in approximately 5 minutes.
- Boil eventual condensed liquid from the inside of the test tube.
- When the test tube has cooled down to room temperature (or just above), take the thermometer away and make sure it doesn't bring any salt while being removed with the spatula. All solid remains of the reaction has to be left in the test tube.
- Weigh the test tube with its contains and calculate the mass of the solid products.
- Calculate how much solid mass could be expected from the three possible reactions by using the molar ratio in reaction formulas 1, 2 and 3. Compare these masses with the test result.

It is reaction formula 2 that describes how sodium bicarbonate decomposes while heated.

Risk analysis: Moderately risky
Waste: Sink