Test and analysis of an atmospheric aerosol collection technique and school outreach within a REXUS project

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Master Thesis

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Sammanfattning


Eftersom uppsatsen skrivs inom ramarna för ett examensarbete på programmet Civilingenjör & Lärare är den tvådelad, en teknisk del och en pedagogisk del. Den tekniska delen beskriver arbetet med testerna av provtagning av aerosolpartiklar vid markytan samt SEM analysen av dessa prover. Den pedagogiska delen beskriver arbetet med att sprida intresse för naturkunskap och teknik genom att utföra skolbesök och presentera projektet RAIN.
Summary

“Rocket deployed Atmospheric probes conducting Independent measurements in Northern Sweden” (RAIN) is a project where the team developed and constructed an experiment for multipoint sampling of aerosol particles in the middle atmosphere. The experiment is launched with a sounding rocket from Esrange in Kiruna March 2012. It consists of two probes which are mounted in the rocket cylinder. They will be ejected from this and fall from about 80 km height. During the fall through the atmosphere the probes collect samples on different heights. The post experiment analysis is done with a scanning electron microscope (SEM). Atmospheric aerosol particles play an important part in cloud formation and have impact on both climate and environment on earth. Sample-taking of them in high altitudes is a problem though and there exists no good technique for this today.

This Master thesis has two parts, one technical and one pedagogical, since it is written within the frames of the program Master of Science in Engineering and of Education. The technical part covers the test of aerosol particle collection at ground level and the post-test SEM analysis of this. The pedagogical part describes the work with spreading interest for science and technology by school visits presenting project RAIN.
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1 Introduction

Sweden has a lot to be proud of as a nation when it comes to technology and science. We have a history of many international successful technology companies. Ericsson, Tetra Pak and Sandvik are just a few of them. In December every year eyes from all over the world are watching when the Nobel Prizes are handed out in Stockholm for the most brilliant discoveries in physics, chemistry and medicine. Since we have this much to be proud of one could almost assume Sweden is a country where science and technology are popular subjects among school students. But this is not the case. A career in the technology or science field attracts very few high school students, also among those who already chosen a science program in high school. This may become a national problem for us and also for many other European countries. An internet search for “lack of engineers in Sweden” gives hints on many concerned newspaper articles about this. Göteborgs Posten (Göteborgs Posten, 2011) writes in a debate article that the lack of engineers is an acute threat for the Swedish economy since technology companies not can find the right competence here and therefore may be forced to move abroad. In the same article it is proposed that schools, science centers and companies have to work together to make science studies more meaningful and interesting for the students. Cooperation between these is proposed to open up for a creative view of the science subject, connect school theories with real world applications and give examples of what an engineer actually does. The writers of the article mean that this has to be seen as an investment of the companies involved and the Swedish communities.

During autumn 2011 I have met over 250 upper secondary school students, presenting an international university student space project I took part in. The purpose of this was to spread interest in the science field among the students. The space project is called RAIN and it has been developing a multi-point collection technique for atmospheric aerosol particles. My part in the project except for the school outreach was to test the technique for collecting the particles. This thesis is about the school presentations I did about RAIN and also about the aerosol collection test and the following electron microscope analysis of it. Since the thesis has two purposes and present two different set of results the structure of it is special. The thesis starts with the background of the science and the project in Chapter two and objectives in Chapter three. Then the technical part of my work is described, the aerosol collection test and the results from this in Chapter four. Chapter five is about pedagogical theories, the school presentation I developed and the implementation and results of this. In Chapter six I have chosen some important threads from the prior text to discuss and then I draw my conclusions in Chapter seven.
2 Background

2.1 Aerosol particles
The RAIN project developed and built a collection technique for atmospheric aerosol particles. Here follows some basic information about the particles. What they are and where they come from, how they have impact on us and why we need to know more about them. All facts in part 2.1 with no other reference are from Chin (2009).

An aerosol is a suspension of solid and/or liquid particles in a gas. There are aerosol particles throughout the atmosphere and the total global mass derives mainly from natural sources like sea salt, desert dust and volcano ash. Dust from the ground and salt particles are found in the troposphere, close to the ground. Volcano ash is thrown up to the stratosphere and high up in the mesosphere there are meteoric dust particles. Humans emit particles in the air through different combustion sources and locally, in regions with many industries and big cities, anthropogenic particles dominate. The atmospheric aerosol particles differ a lot in sizes between a few nanometers to some tens of micrometers. They have different compositions, shape and physical properties. They interact differently with sunlight and react with other aerosol particles and gases in the atmosphere therefore the atmospheric chemistry is a very complex matter.

The atmospheric aerosol particles have big impact on the climate, environment and our health. They acts as condensing nuclei and are therefore an important part in cloud formation and circulation of water on earth. There is also an increasing interest in them since the particles seem to have a general cooling effect on the planet. This is because many of them and the clouds they form scatter sunlight. All atmospheric aerosol particles do not have this effect though some even reflect heat just like greenhouse gases. Many anthropogenic particles pollute the ground and air, give acid rain and make animals and humans ill in different lung diseases. The atmospheric chemistry is a very complex matter and much research is still left to be done to understand more of it and what the impacts are on the planet.

In the stratosphere and mesosphere volcano ash respectively meteoric smoke are proposed to play an important role in different cloud formations (Hedin, Gumbel & Rapp, 2007). For example there have been observed layers of metal particles in the mesosphere, left there by the meteors. Not much is known about how these metal particles react with their surroundings, the properties of the products and distribution in the atmosphere (Hedin et al., 2007). The reason is that it is not very easy to take samples this high up where weather balloons not reach. A problem with sample collecting in the mesosphere, which is need to be done with a sounding rocket, is that the smallest particles rather go with the air stream around the collection equipment than hit it (Hedin et al., 2007). There has also been a problem with avoiding rocket smoke in the collection equipment.

2.2 RAIN experiment
Project RAIN works in association with the Department of Meteorology at Stockholm University (MISU) and wants to contribute to the atmospheric aerosol particle research. Here follows some
background information about project RAIN, the experiment RAIN developed and why outreach is an important part of it.

REXUS is a European program where groups of university students design and build experiments for a sounding rocket, which launches from Esrange in Kiruna. The REXUS program is arranged, sponsored and supported by Swedish National Space Board (SNSB), German Aerospace Center (DLR), European Space Agency (ESA) and Swedish Space Cooperation (SSC). A student team from Kungliga Tekniska Högskolan (KTH) and Department of Meteorology at Stockholm University (MISU) has since autumn 2010 been working with one of these experiments called RAIN. The purpose is to develop and validate a technique for multipoint aerosol sample collection in the mesosphere and stratosphere.

The rocket will carry two collection probes or free falling units (FFU). The FFUs are mounted inside the rocket cylinder and will be ejected at about 60 km height. The rocket cylinder is called the rocket mounted unit (RMU). Figure 2.1 shows the procedure of the experiment. The FFUs will reach an apogee at about 80 km. They will be ejected far from the rocket to avoid a fall thorough the smoke that the rocket leaves behind. On the “earth facing” side of the FFUs there will be holes in the surface exposing sample holders on a rotating plate. During the fall between 80 km to 15 km every sample will be exposed for about 5 seconds each. In this way samples from different altitudes will be collected. At about 6 km above ground a parachute will deploy to slow down the probes. The FFUs will be recovered and the samples will then be analyzed in a scanning electron microscope (SEM). Distribution, size and eventually composition of the aerosols will be analyzed. Figure 2.2 shows the rocket cylinder with two FFUs inside.
One important part of the project is the outreach and connection to the public and groups that may be interested in the project. RAIN has had a website, a blog and Facebook page since the beginning of the project. During spring 2011 some members also visited high schools and a youth space camp to present the project. The school presentation has then developed during autumn 2011 and more schools have been booked for visits. The outreach activities and publicity are important for the organizers and sponsors of the project. It is important for them that ambitious young people who are about to choose career more often consider choosing a technology related one, since there is a lack of competence in the area. Exciting projects like RAIN may inspire them to do so.
3 Objectives

3.1 Objectives for a technical and a pedagogical part
This master thesis has two parts, one technical and one pedagogical. The pedagogical purpose is to work with outreach and develop school visits. The RAIN project aims to reach out to upper secondary school students and try to spread an interest in science and technology. To succeed with this, both the content and the didactic aspects of the school presentations need to be considered. The technical purpose is to investigate the performance of the aerosol collection experiment. That is how well aerosol particles stick to the samples in tests on the ground, if the FFU leaks in aerosol to not exposed samples and if the FFU itself contaminates the samples.

3.2 Question formulations
There are two main questions being handled. The first one is based on the outreach part and the second is raised from the aerosol collection test:

1. How can an inspiring 50 minutes long one-occasional presentation be setup for high school students, with the purpose to make them interested in science and technology?
   - How should it be structured?
   - What should be the content?
   - What are the potential benefits and problems of making the presentation partly interactive?

2. How well does the aerosol collection experiment work?
   - Are the FFUs contaminating the samples or are particles leaking in to unexposed samples?
   - What kind of aerosol particles can be collected and observed in posttest analysis, size and chemical composition?

3.3 Methods
The first question is answered by literature studies in learning theories about structure and content, but also in general attitudes to the subjects among young people. A presentation about RAIN is constructed and the student reactions are documented with two assessment methods, a questionnaire and interviews.

The second question will be answered by performance and analysis of the aerosol collection test. The methodology for this test is described in detail in chapter 4.3.

3.4 Deliverables
There are two concrete outcomes of this work. The first is the construction of presentations about project RAIN and its purpose, suitable for the target group, and assessment of this. The
second is routines for the aerosol collection experiment. Both of those activities are also going to be documented. The deliverables are:

- Construction of school presentations about RAIN.
- Documentation of the results from presentations assessments.
- Routines for preparations and loading of the aerosol collection sample holders.
4 Aerosol collection test

4.1 Aerosol collection experiment
To collect atmospheric aerosol particles the RAIN experiment uses collection probes or free falling units (FFU). In the FFU there are sample holders on a rotating collection plate. Every sample will be exposed once to the atmosphere during the fall.

4.1.1 Aerosol collection compartment
The aerosol collection compartment is situated in the bottom part of the FFU, Figure 4.1 shows this.

Sample holders are placed on a rotating gear, called the aerosol collection plate (showed in Figure 4.2), which is driven by a motor. The sample holders have standard dimensions to fit in an electron microscope for post flight analysis. On each sample holder there are five sample beds which each are loaded with a target material. Figure 4.3 shows a loaded sample holder. Three different target materials are being used and they are described closer later in this chapter. A sample bed loaded with one of the target materials is called a sample. When the collection plate is filled with loaded sample holders, everything is constrained with a lid which has openings for the samples. The whole collection compartment is closed by the base plate in the FFU. To get less friction between the collection plate lid and base plate a teflon sealing is glued on the top of the lid. In the base plate there are two openings which expose the samples as the aerosol collection plate rotates.
4.1.2 Sample holder cleaning and loading procedure

It is important that the whole aerosol collection compartment is clean before it is loaded with the target materials. Otherwise there is a risk that the samples are contaminated of particles from the FFU itself. It is therefore important with a proper cleaning procedure. Appendix 4 contains the cleaning and loading procedure I have written. During this procedure it is important to use gloves and a coat and as much as possible work in the clean room where the air is clean and no dirty tools are used. The cleaning of the sample holders will be done just before the loading. All the parts of the collection compartment are needed to be cleaned. The last thing happening in the assembly procedure for the FFU is to load the sample holders and put the collection compartment together.

4.1.2.1 Cleaning

All parts that can be taken loose from the FFU will first be put in a sonic bath (Figure 4.4). The sonic bath is filled with water. When high frequency sound waves go through the liquid there will emerge small vacuum filled bubbles when the compression waves “tear” the water apart. These bubbles will implode fast, releasing energy as heat and pressure waves. This process is called cavitation, and the pressure waves are powerful enough to remove dirt like dust and organic materials on metals (Ultrasonics, n.d.).
After the ultra-sonic bath all the loose parts should be cleaned with ethanol. Also the FFU itself should be wiped off with ethanol and then dried with high speed air.

### 4.1.2.2 Loading procedure

When the sample holders are clean and dry, the sample beds are ready to be loaded with target materials which is a procedure also described in Appendix 4. All loading is done in a clean room. Three different target materials are used in different sample beds for the aerosol particles collection. The purpose of this is to try how well the different materials collect different types of particles and how effective they are to handle in the post experiment analysis. When the sample holder loading procedure is finished, the FFU assembly procedure goes on with the collection compartment.

#### 4.1.2.3 Silicone gel

The first target material being loaded is a silicone gel. This is an optically clear, soft silicone gel of the name Nusil gel 8100 (Figure 4.5). It is mixed together from two liquid components 1:1 and a small droplet of the mixture is applied in the sample beds with a capillary. After being dried in an oven at 100˚ for an hour, it forms a sticky gel and is ready to be used. Because the sample holders with the applied gel need to be in the oven, the loading procedure starts with this.

When the aerosol particles hit the gel during flight they will not penetrate it completely but be stuck on different levels in it and just some are visible on the surface. The gel is not conducting which makes it hard to get a good focus in the SEM analysis. Because of this the gel samples need to be sprayed with a conducting material to make the SEM analysis of it possible.

![Figure 4.5: Picture of gel components](image)

#### 4.1.2.4 TEM grids

When the sample holders are ready in the oven and cooled for a while it is time to put on the copper and formvar resin coated carbon grid, shown in Figure 4.6. This kind of grid is commonly used in transmission electron microscopy (TEM), therefore copper and formvar resin coated carbon grid is often called a TEM-grid. The grid is put in place in the sample beds with a good tweezers, which can hold the grid tight on its very edge and gives a firm but good grip. It is very important to be extremely careful and only touch the grid on the edges otherwise it is easy to damage the formvar film on the grid. A damaged formvar film spreads small particles all over the grid.
During flight aerosol particles are captured on the formvar film. Bigger particles, 10 µm or more, will probably not stick to the film but the grids are better for collecting the really small particles 500 nm or less. The sides of the squares in the grid are about 60 µm and make it easy to locate and focus in the post-test SEM analysis. The dimension of the sample beds in the sample holders were designed to accommodate the 3 mm diameter TEM grids and they are therefore easily loaded in the sample beds.

4.1.2.5 Glass fiber filter

The third target material we are using is glass fiber filter. When aerosol particles are collected close to the ground it is common to use this since. The filter is cut to the right diameter size, 3 mm, by a homemade tool, Figure 4.7 shows this. The tool is a pipe with a sharp end, 3 mm in diameter. The filters are put on the sample holders with a tweezers.

The glass fibers create a net in which the aerosols can be captured, shown in Figure 4.8. We use a glass fiber filter where the holes in this “net” are about 500 nm. This means that smaller particles will go through it and we will only collect bigger particles with the filter.
4.2 Scanning electron microscope (SEM)

The analysis of the samples is done with a scanning electron microscope of the brand JOEL JSM-7401F (Figure 4.9). Following text is based on facts from Egerton (2005), and describes the function of the SEM we are using.

![Figure 4.9: Picture of JOEL JSM-7401F (From JEOL, n.d)](image)

4.2.1 Operation principle

De Broglie proposed in the early 20th century that the wavelength $\lambda$ of a particle like the electron is given by:

$$\lambda = \frac{h}{p} = \frac{h}{mv}, \quad [1]$$

where $h$ is the Planck constant, $p$ is the momentum, $m$ is the mass and $v$ the speed of the particle. If an electron is emitted from a source into vacuum and accelerated through a potential difference, the wavelength of the electron decreases. The wavelength of an electron can therefore be adjusted by changing the voltage. This is used in SEM technology to create electron beams with suitable wavelength for interactions with the sample.

Electrons emitted from an electron gun are accelerated in vacuum and are deflected by magnetic lenses in to a thin beam and scanned over the sample. The electrons will interact with the material through elastic or inelastic scattering. In elastic scattering the electrons are “reflected” by the atomic nuclei in different directions without almost any energy lost. Some of them will be backscattered changing their direction almost 180°. Since elastic scattering depends on the charge of the nuclei, backscattered electrons (BSE) detected will give information about the chemical composition of the sample.

In inelastic scattering the incoming (primary) electron interacts with atomic valence electrons and can supply these with energy, releasing them as secondary electron (SE). Only SE close to the surface will manage to escape in to the vacuum and therefore detected SE brings information
about the topography of the sample surface. These SE emitted have also much lower energy than the BSE and the two different types of electrons can therefore easily be distinguished.

If the incoming primary electrons have enough of energy they can also excite inner shell electrons which emit x-ray photon when they are de-excitated. The energy of the x-ray radiation depends on the nuclei charge, and is characteristic for every element. This can be used to decide the chemical composition of the sample.

Detectors collect SE and translate this to a signal which gives us a three dimensional picture of the sample. The BSE gives a variation in grayscale of the sample picture which depends on the chemical composition. X-ray photons detected give information about which elements are present in a small area of the sample. Figure 4.10 shows the operations principles for a SEM.

![Diagram of SEM components](image)

**Figure 4.10: Operations principles of SEM (From How stuff works, 2009)**

### 4.2.1.1 The electron gun

In the SEM used for our samples the electron gun is of the type cold field electron emission (cold FEG). The cathode of the electron gun is a sharp v-shaped filament made of tungsten. If the electrostatic field at the tip increases the energy barrier the electron must overcome to escape the surface decreases. Electrons pass through this potential barrier in vacuum because of the tunneling effect, and the process is called field emission. The voltage at the tip is about 6 kV, and will make the electrons steam out from the filament. Figure 4.11 shows an electron gun.

When the electrons are coming out from the electron gun, their kinetic energy must be adjusted to get a wavelength which is suitable for the information we want about the sample. An electron with larger wavelength will not go so deep in the sample but produce more SE from the surface and give information about the topography of the sample. A smaller wavelength will make the
Electrons go deeper in the sample and produce more BSE and x-ray photons, giving information about the chemical composition. So to adjust the wavelength an anode is situated further down on the optic axis, this is also seen in Figure 4.11. The anode is a round metal plate with a hole in the middle, through which the accelerated electrons go. The voltage can be regulated to get a suitable kinetic energy of the electrons.

Figure 4.11: Electron gun (From Northern Arizona University, 2006)

4.2.1.2 Magnetic lenses
To focus the electron beam a coil carrying a direct current are used. The coil produces a non-uniform magnetic field around itself. When an electron passes through the field, there are a force acting on it which varies throughout the field in both magnitude and direction, shown in Figure 4.12. This force changes the direction of the electron, and by varying the strength of the magnetic field we can manipulate the way of the electron beam. In a SEM there are several lenses having different purposes.

Figure 4.12: Magnetic lens (From: Wikipedia, 2011)

4.2.1.2.1 Condenser lenses
It is important that the electrons in the beam have the same wavelength, because we want all electrons to reach approximately the same deep in the sample. This is not the case when they leave the electron gun though. To make the beam "monochromatic" there is first a strong condenser lens spreading the different wavelengths in different directions. Only electrons with
similar wavelength will continue parallel to the optical axis. Directly after this there will come one more condenser lens, a weak one collecting the electrons to a thin beam. The condenser lenses can be seen in Figure 4.10.

4.2.1.2 Scanning coils
The scanning coils move the beam over the sample in two perpendicular directions. This procedure is called the raster scanning and makes the beam to scan a rectangular area, a raster, on the sample. The magnification depends on how big the raster is the picture shown at the screen is the raster square.

4.2.1.3 Objective lens
The last lens closest to the sample is called the objective. It forms a very small probe and gives the focus of the picture.

4.2.1.3 The sample stage
The sample must be held on place tightly in the microscope and stand the high vacuum in the SEM. Every small vibration could disturb the pictures. All samples are round, 3 mm in diameter and situated in special holders with a top securing the sample. To load the SEM the sample is put in an airlock. After the airlock has been closed the pressure decreases to the same level as in the actual microscope. When the pressures are the same, the airlock open up to the microscope and the sample is pushed in. It is possible to adjust the sample up and down to get good focus. Samples that not are conducting may be needed to be sprayed with something making it so. Otherwise the samples are charged up and the picture gets too bright. Often the samples are sprayed with gold or patina, this also protect the surface of biological materials which otherwise are destroyed by the electron beam.

4.2.1.4 The image
The image is produced by primary and secondary electrons, giving different information about the sample. But also x-ray photons leaving the sample are giving information.

4.2.1.4.1 Secondary-electrons (SE) images
SE are valence electrons being released from the sample because of inelastic scattering. Only electrons close to the sample surface are able to get out to the vacuum, the average depth for this is less than 2 nm and is called the escape depth. The information that we get from detected SE are therefore about the surface, the topographical contrast. The average number of escaping SE per primary electron is called the SE yield, \( \delta \). For given sample \( \delta \) decreases with increasing energy of the primary electrons, because higher energy primary electrons will undergo less inelastic scattering and generate fewer SE within the escape depth. The SE yield are less for a flat surface than for a "slope surface". This is because the volume from which the SE can escape is greater for a non-flat surface. This is shown in Figure 4.13.
Surface variations facing the detector will also give better signal because electrons coming from this area have a higher probability of hitting the detector. Because of this it is possible to make a three dimensional picture. The sample is often tilted towards the detector and electrons from surfaces facing it will more often hit the detector. This will create a brighter area in the picture. *Figure 4.14* shows a crystal where this “shadow effect” is clearly shown.

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**Figure 4.13: Electron yield on surface (From Northern Arizona University, 2008)**

**Figure 4.14: Chrystal with "shadows" (From Scanning electron microscope, n.d)**

4.2.1.4.2 Backscattered-electrons (BSE) images

The BSE are primary electrons elastically scattered of the atomic nuclei. They do not lose much energy in the interaction with the sample and have much higher energy than the SE escaping the sample. The two different electrons can therefore easily be distinguished by an energy filter. The fraction of backscattered primary electrons is called the backscattering coefficient, η. η increases with higher atomic number because of the higher probability to be scattered by the bigger nuclei. The BSE give information about differences in chemical composition of the sample. This is seen as differences in the grayscale on the picture. For example, an area of pure Fe on the sample produces more BSE than an area of FeO. Therefore the pure Fe area gives a stronger signal and a brighter spot on the screen.
4.2.1.5 Everhart-Thornley detector

The most commonly used detector in electron microscopy is the Everhart-Thornly (ET) detector, which can detect both SE and BSE. *Figure 4.15* shows principles of the ET detector. The electrons leaving the sample are accelerated toward a *scintillator* that is highly positively charged. The scintillator is a layer of phosphor on a glass rod made conducting by a thin metallic surface coating. It has the property of emitting visible light photons when hit by charged particles, called cathodoluminescence. The greater kinetic energy of the secondary electrons the more photons are released. The photons pass through the glass rod which continues to a photomultiplier tube (PMT) outside the vacuum.

The PMT is a sealed glass tube containing high vacuum. The light entrance surface is coated with a thin layer of a material which acts as a photocathode. The photons release valence electrons, so called photoelectrons, in the photocathode which escaping in to the PMT vacuum. The photoelectrons have low energy and are accelerated toward the first of a series of positive dynode electrodes. They release a cascade of secondary electrons which are accelerated toward the second dynode, where they release one even bigger cascade of secondary electrons. This is repeated for several times and amplifiers the $\delta$ signal with a factor of $10^6$. The good thing with this quite complicated detector is that it gives a good amplification with relatively little noise.

![Figure 4.15: Picture of ET detector (From Everhart Thornley detector, 2007)](image)

The ET detectors can be placed on different places in the microscope. In high-performance field-emission-gun electron microscopy (FEG SEM), which we are using, it is usual to have two detectors placed in different angles from the sample. One detector is placed in the objective lens (secondary electron imaging, SEI) and one is placed under the lens a bit to the side of the sample (lower electron imaging, LEI).

The SEI detector detects both SE and BSE and gives often a stronger signal than the LEI detector. The objective lens is creating a strong magnetic field which reaches the sample plane. The magnetic field traps the electrons escaping the sample and they spiral up along the magnetic field, where they hit the detector. An energy filter separates SE from BSE. The advantages with
the SEI detector are that it attracts more electrons and give a stronger signal, it gives less good “shadow effect” and therefore an additional LEI detector is sometimes preferable to use.

### 4.2.1.6 Detecting characteristic x-ray photons

There are also photons emitted from the sample when the electron beam hits it. If a primary electron from the beam excites an inner shell electron in the sample, a photon with higher energy will be emitted as a characteristic x-ray photon. The energy of the x-ray can be measured with an energy dispersive spectrometer and are used to identify the atomic number of the atom it came from. The picture from the characteristic x-ray signal will show an elemental map, the distribution of a chemical element in the sample. Figure 4.16 shows an element map. This kind of analyzes takes a lot of time though. It is also possible to scan a part of the sample and get the elements present in weight percent or atom percent. That is a procedure which takes less time.

![Image of X-ray elemental map](image)

**Figure 4.16: X-ray elemental map (From Union Collage N.Y, n.d)**

### 4.3 Test methodology

The aerosol collection technique went through three different tests. First clean samples had to be analyzed in the SEM, ensuring the cleaning and loading procedure was made properly. In the second test a sample holder was put in the FFU and rotated one round before analyzed in the SEM, this would show if the FFU itself contaminated the sample. For the third test the fully assembled FFU was held outside a car window and in high speed exposing the samples in the same way as it would in the real flight, followed by SEM analysis.

SEM analysis gives information about size, form and composition of the particles analyzed. The picture can tell if a particle is amorphous or crystalline, spherical or irregularly formed. Because it takes very long time to do the analysis of many samples, the numbers of aerosol particles collected and their size and form will primary be observed. Chemical composition of the most interesting particles will be analyzed.

![Image of TEM grid](image)

**Figure 4.17: Grid and the four quadrants. Control squares are marked green.**

The TEM grids have a mark in the middle which divides them into a coordinate system with four quadrants making it easy to name and navigate between certain squares in the grid, see Figure 4.17. We called the quadrants for A, B, C, D and because the analysis take very much time primary square 4,4 in every quadrant will be analyzed. They are called the control squares.
4.3.1 Analysis of clean sample holders
Eight new and hopefully clean TEM grids were first analyzed in the SEM. They were not loaded in the RAIN experiment sample holders, because there were no lids to hold the grids in place manufactured yet. Without lids there was a risk that the grids would leave the sample beds inside the SEM when the vacuum was being created. Instead they were put in another sample holder with a lid commonly used in the SEM laboratory. Since the same grids were going to be used later in the FFU contamination test and car test, they had to be moved from this other sample holder to the RAIN experiment sample holders after the analysis. This meant an extra risk to contaminate or scratch the grid. Table 4.1 shows which grid that was used in the following tests and which ones that was exposed to the air and which was only control samples.

<table>
<thead>
<tr>
<th>Grid no</th>
<th>Used in test</th>
<th>Exposed to atmosphere during test</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Contamination test</td>
<td>No</td>
</tr>
<tr>
<td>2</td>
<td>Car test</td>
<td>No</td>
</tr>
<tr>
<td>3</td>
<td>Car test</td>
<td>Yes</td>
</tr>
<tr>
<td>4</td>
<td>Car test</td>
<td>Yes</td>
</tr>
<tr>
<td>5</td>
<td>Car test</td>
<td>Yes</td>
</tr>
<tr>
<td>6</td>
<td>Car test</td>
<td>No</td>
</tr>
<tr>
<td>7</td>
<td>Car test</td>
<td>No</td>
</tr>
<tr>
<td>8</td>
<td>Car test</td>
<td>No</td>
</tr>
</tbody>
</table>

4.3.2 FFU contamination test
One sample holder was loaded with grid no 1, which we knew from the first test was a clean and not damaged grid. The sample holder was also loaded with one glass fiber and gel. Two sample beds were empty. The sample holder was then put in to the FFU and rotated one round. A SEM analysis of those samples was done directly after and pictures of the grid before and after could be compared. Pictures were also taken of the gel and glass fiber samples, but only after the contamination test. The purpose was to ensure the FFU itself did not contaminate the samples.

4.3.3 Car test
In the last test seven sample holders were loaded with grid no 2-8 from the first test and also glass fiber and gel. They were then put in a FFU which were stuck to a piece of wood and held outside a car window, while the car was driving about 90 km/h. The collection plate was rotated and exposed the samples stepwise for 10 seconds each. When we analyzed the samples we were using the special made top for the sample holders, so we did not need to move the grids to another holder for the analysis.
4.4 Results aerosol collection test
Here follow the results from the SEM analysis of the three different tests.

4.4.1 Results from analysis of clean sample holders
The SEM analysis of the eight clean samples loaded with TEM-grids showed that some of the grids had broken polymer films, probably caused by the tweezers. The broken film caused small particles all over the grid. Round holes from manufacturing could also be observed. The manufacturing holes were not disturbing the analysis though. Their presence was good in one way because they ensured us we had focused on the formvar film. A bad focus can easily be mistaken for a clean grid. The grids which had no damage did not show any clear traces of contamination from the loading procedure or manufacturing.

4.4.1.1 Grid 1
Grid one had no holes made from the tweezers and as long we could see no particles on the formvar film. Figure 4.18 shows the control squares in the four quadrants of the grid. There can be seen some holes from manufacturing. The holes are round and look like darker dots on the pictures. Figure 4.19 shows a magnification of one of them. Holes made from a tweezers would be bigger and look more “torn” than the manufacturing holes.

Figure 4.18: Control squares in grid 1
4.4.4.2 Grid 2

Figure 4.20 shows the control squares in the four quadrants of grid two. In all of them there can be seen small white dots, it is particular easy to see in quadrant C. The darker squares around the white particles in Figure 4.20 are damages in the formvar film caused by the electron beam while scanning the area. Grid two had a hole in the formvar film, probably caused of the tweezers in the loading procedure. This damage is probably the source of the particles found on the film. Figure 4.21 shows the hole and a magnification of one of the particles.
4.4.4.3 Grid 3

On grid three we could see some particles on the film and quite many holes from manufacturing. Figure 4.22 shows the control squares in the four quadrants of grid three. The manufacturing holes are seen as black dots on the squares. Figure 4.23 shows magnifications of two particles found on the grid. We did not observe any holes from loading procedure on grid three.
4.4.4.4 Grid 4

There were some particles on the film and holes from manufacturing on grid four. Figure 4.24 shows the control squares in the four quadrants. We found a hole which could come from the loading procedure, see Figure 4.25. The same figure also shows one particle found on the grid.

Figure 4.23: Magnification of two particles found on grid three

Figure 4.24: Control squares in grid 4
4.4.4.5 Grid 5
Grid five was quite clean, but there were many manufacturing holes. This is seen as back dots in Figure 4.26 which shows the control squares in the four quadrants.

4.4.4.6 Grid 6
Grid six had some particles on the film seen as white dots in Figure 2.27, which shows the control squares.
4.4.4.7 Grid 7

Grid seven had some particles but was quite clean as well. Figure 4.28 shows the control squares in the four quadrants.
4.4.4.8 Grid 8

Grid eight had some particles, especially on the controlled square in quadrant C but showed no other traces of bigger contamination. Figure 4.29 shows the control squares. Figure 4.30 shows the magnification of one particle found.

Figure 4.29: Control squares grid 8

Figure 4.30: Particle on grid 8
4.4.2 Results FFU contamination test
The FFU itself seemed not to contaminate the samples very much. The pictures of the grid before and after the FFU contamination test did not show any new particles what we could see. There were a few particles found on the glass filter though. It was hard to get any focus at all on the gel sample and there for we did not get any result from this.

4.4.2.1 Grid 1
The before and after pictures of grid one did not show any new particles on the grid. It was hard to see smaller particles on the film though. Figure 4.31 shows two of the control squares before and after the contamination test.

![Figure 4.31: Control squares in quadrants C & D, before and after car contamination test. Grid 1](image-url)
4.4.2.2 Glass fiber filter
On the glass fiber filter two kind of particles were found. The results of the x-ray analysis of this are showed in Figure 4.32 and Figure 4.33. An x-ray analysis was done on both the particles and on the glass fibers, so the chemical compositions could be compared. Figure 4.32 seem to show a fiber and Figure 4.33 aluminium containing particles. The aluminium could come from the FFU and the fiber could come from the teflon “mat” between the aerosol collection plate sealing and the baseplate.

Figure 4.32: Fiber found on glass fiber filter after contamination test
4.4.3 Results car test
We found larger particles on samples loaded with glass fiber filter and gel after the car test. Still it was hard to see if any smaller particles had been caught on the grids. We also had a problem with the grids leaving the sample beds during analysis when vacuum was created in the microscope. An x-ray analysis was not possible to do on the grids because the aluminum signal from the sample holder itself became too big. But on the gel and glass fiber filter we could determent elements present in the particles found with help of x-ray analysis.

4.4.3.1 Grid 2
Grid two had not been exposed during the car test. We could not see any new particles on grid two during analysis. Figure 4.34 shows before and after pictures of three control squares.
4.4.3.2 Grid 3
Grid three had been exposed during the car test, but came out of the sample bed when the vacuum was produced in the microscope. Even if we tried to put it back on place it kept moving inside the microscope and it was hard to get any good pictures. Because it had been outside the sample bed it would be hard to tell where new particles came from if we would see any. Therefore not much effort was put on get good pictures of this grid.

4.4.3.3 Grid 4
Grid four was probably damaged by the tweezers. Figure 4.35 shows before and after pictures of the control squares in quadrants A, B and D. The pictures are taken with different detectors, LEI or SEI. This makes it hard to compare them. It also seems like the before and after pictures in some cases was not the same square, see Figure 4.35 D.
4.4.3.4 Grid 5

On grid five, which had been exposed during the car test, we found new particles in the size of some hundreds nm in the controlled squares, Figure 4.36 shows this. But grid five was also scanned in bigger areas. The reason for this was that we had looked upon the gel samples earlier and found bigger particles and we wanted to compare the two materials and see if we could find the same particles on the grids. We did find many bigger particles on the grid that looked like the same sort we had seen on the gel samples, Figure 4.37 shows some examples. An x-ray analysis to determine the presence of elements was impossible to do on the grids in our aluminum sample holder. This was because when the accelerating voltage was raised for the x-ray analysis the electron beam went through the thin film and gave a strong background signal from the metal. If we would have moved our samples to another holder, it would be possible to do an x-ray analysis.
4.4.3 Glass fiber filter
On the glass fiber filter there were bigger particles, up to approximately 70 µm. Figure 4.38 shows four of them. An x-ray analysis showed the composition of some. This was possible to do on the glass fibers in the RAIN aluminum sample holders because the fibers are much thicker than the film on the grids. Figure 4.39 shows a particle that consists of C, O and Si. To be sure the signal is not from the glass background, the glass is being analyzed too and the two spectra coming up are compared.
Figure 4.38: Particles found on glass fiber filter after car test

![Figure 4.38: Particles found on glass fiber filter after car test](image1)

Figure 4.39: Particle and its composition on glass fiber filter

![Figure 4.39: Particle and its composition on glass fiber filter](image2)

<table>
<thead>
<tr>
<th>Spectrum</th>
<th>In atm</th>
<th>C</th>
<th>O</th>
<th>Si</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectrum 1</td>
<td>Yes</td>
<td>88.92</td>
<td>10.92</td>
<td>0.17</td>
</tr>
<tr>
<td>Spectrum 2</td>
<td>Yes</td>
<td>31.89</td>
<td>30.67</td>
<td>37.44</td>
</tr>
<tr>
<td>Spectrum 3</td>
<td>Yes</td>
<td>77.23</td>
<td>22.46</td>
<td>0.22</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>66.01</td>
<td>28.01</td>
<td>5.94</td>
</tr>
<tr>
<td>Std. deviation</td>
<td></td>
<td>3.14</td>
<td>26.45</td>
<td>0.56</td>
</tr>
<tr>
<td>Min.</td>
<td></td>
<td>58.83</td>
<td>30.67</td>
<td>37.44</td>
</tr>
<tr>
<td>Max.</td>
<td></td>
<td>88.92</td>
<td>10.92</td>
<td>0.17</td>
</tr>
</tbody>
</table>

All results in atomic%.
4.4.3.6 **Sticky gel**

The gel was first analyzed with some carbon fibers on the top, which would help to get focus. This was successful and we could see particles on the surface of the gel. But it was not possible to do an x-ray analysis, because the high accelerating voltage needed for this would destroy the sample.

The sample was then sprayed with gold. This protected the sample from being destroyed by the high energy beam. It also made the surface conducting and charges that before had made it impossible to get any pictures was led away. With this technique it was possible to get good focus and to do x-ray analysis of the sample.

Big particles about 100 µm and small particles down to 100 nm could be observed. It could be a little hard to decide the size since what was seen on the surface could be the "top of an ice berg". There were also marks on the surface where particles had hit and gone in to the gel, no longer visible with low accelerating voltage of the beam. **Figure 4.40** shows some particles found on the gel surface.

Particles containing Na, Cl, F, K were found. They could come from road salt. There were also particles containing Ca, O, C and others containing Si, O and C. That could be particles from the asphalt. **Figure 4.41** shows a picture from an x-ray analysis of what may be a salt particle.

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![Figure 4.40: Particles on gel surface after car test](image)
Figure 4.41: Chemical composition of a particle found on the gel surface
5 School presentations

5.1 General attitudes to natural science and technology
The purpose of presenting RAIN in upper secondary schools is to spread an interest among young students in natural science and technology. The idea is to give a picture of what higher education in the subjects could be like and to make them more willing to apply for these kinds of studies. To do that it can be necessary to analyze what general attitudes Swedish students have to those subjects, so we know what to focus on in the presentations. In this part of the thesis we are looking closer on what young girls and boys think about the subjects we work with in the RAIN project. The ROSE project at Oslo University has documented the attitudes towards natural science and technology in different countries and the results from this give a picture of the general attitudes among young people in Sweden.

5.1.1 The ROSE project
ROSE is a large international comparative project based at the University of Oslo. ROSE stands for ‘the Relevance of Science Education’ and its purpose is to document and compare 15 years old students’ attitudes to natural science and technology. In 2003 ROSE collected data about attitudes from students in about 40 countries all over the world. The questions were about their opinion of science and technology in school but also as a possibility of career in the future. ROSE also compared what topics within the field of science and technology the students wanted to learn about. The results from ROSE have been used to develop the school education in these subjects. By actually asking the students what they are interested in, the education in these subjects can become more meaningful for them. In Sweden 751 students participated in the ROSE study. All the facts about ROSE in this chapter with no other references are from Sjöberg (2005).

5.1.1.1 Attitudes according to ROSE
The ROSE project clearly shows that young people in all Nordic countries have a quite negative attitude to natural science and technology. Swedish students do not like natural science compared to other school subjects and they do not want as much lessons of this as possible. Boys are generally more interested in the technology areas than girls, and are more positive to take a job that has to do with machines and tools. Girls are more attracted to “work with people” than with tools or technology. "Work with people" is also popular among boys but not as much as among girls.

What is really interesting is that these trends of attitudes between genders are not as pronounced in the rest of the world as in the "Western countries'. The general opinion of these subjects is also more positive in countries outside the Western world. That means we cannot say this is biological differences in interests between girls and boys or that science must be a boring subject in school compared with other subjects, suitable only for a few students. So we can, and must, ask ourselves how we will make science classes meaningful and joyful for both girls and boys in Sweden today.

5.1.1.2 What do young people want to learn about according to ROSE?
The ROSE study picked out 108 different topics within science and technology and asked the students what they would find interesting to learn about. The most popular topics among
Swedish students showed to be the ones about the body, health and diseases. Space and phenomena we cannot explain are also popular (Jidesjö et al. 2009).

The least interesting topics are those related to everyday life, like how food is produced and how soap and detergents work etc. There are some differences between genders here as well. Girls seem to be more interested in supernatural things and science related to the body and soul, while boys are more attracted to bombs, new technology and explosive chemicals. The ROSE study also shows that there is no clear difference between popular topics among students who plan to study science in the future and those who not plan to do so (Jidesjö, Oscarsson, Karlsson & Strömdahl, 2009).

5.1.2 How do we choose what to study/work with?
There are of course many reasons for people to do certain choices in life. But when the trends between gender and country of residence are as clear as the ROSE project shows, one must wonder if there are general reasons for young people to make those choices. In a postmodern society, like ours, people have an idea about a free choice of life style. When basic needs are satisfied we are longing for new more sophisticated ones and on the top of the pyramids of needs we find the freedom of personal choice and fulfillment of the personal dreams (Maslow, 1943). That those choices are completely free can be considered questionable though. If we look on empirical studies, it is quite clear that we do stick to the path our parents went along. Social reproduction is strong even in our postmodern society (Schreiner, 2005). If the RAIN presentation wants to attract young people to a career as an engineer or scientist we therefore need to understand what they think is important factors in their career choice. But also to connect the picture the students have of an engineer or scientist with something they can relate to and imagine themselves as.

5.2 Presentation design concepts
To make the school presentations about RAIN understandable, interesting and engaging it is not only the level of “entertainment” in the content that is important of course. The structure is also very important. Different representations of a concept can make our message clearer to the students. But we also need to structure all the information in the presentation and make sure the load of information is not too heavy. Interesting parts of the content may need to be removed in order to concentrate a clear message of the presentation.

5.2.1 Multiple representations
Often we use pictures to demonstrate something we are explaining in a text or verbally. Many empiric studies have been done on how pictures help students understand complex processes and most of them show that especially poor readers do get a better understanding for the overall message (Kozma, 1991).

There are many different external representations the students can build their own mental models (or internal representations) from. Examples of this are written or spoken text, static or animated pictures, films, sounds and music (Schnotz, 2002). The computer, all its programs and internet give us an extraordinary chance to explain and show scientific phenomena and models in different ways with pictures and text etc. We can combine these representations in different ways and also with “hands-on representations” like experiments. Some combinations can give a
better comprehension of a phenomenon. A picture, for example, may make a written text more understandable.

Mayer (2003) states this is because visual and verbal representations connect to different processing channels in the human brain, so called dual coding. Schnotz (2002) thinks however this theory is too simple. From his point of view different representations use different sign systems which can, but not necessarily have to, connect to and strengthen each other. He therefore states that pictures together with text, where the two representations do not have a one-to-one connection, also can have a negative influence on learning.

5.2.1.1 Dual coding
The psychologist Allan Paivio (1990) has proposed that the human brain has an information-processing system consisting of two separate channels or cognitive subsystems. One is the verbal channel which process spoken text and sound representations. The other one is the pictorial channel for visual input such as written text and pictorial representations. The two channels have limitations in how much information they can handle at the same time. This is called the dual coding theory and is based on observations of how we remember things with help of pictures. Figure 5.1 shows the organization of this theory. Spoken words and sentences are proposed to only be processed in the verbal system, but pictures and written text are encoded in both systems and make therefore a stronger impression which lasts longer in the memory than verbal input do.

Mayer (2003) means that verbal or pictorial representations lead to different mental models based on the verbal or visual input. An external auditory representation leads to a propositional text-based mental model, and a visual input leads to an internal model image. These visual or verbal mental models are then integrated in a one-to-one mapping process, which only will happen if the visual and verbal mental models are activated in the working memory at the same time. This means that a picture will help understanding of a spoken text only if it is presented close in time with the text. Based on this theory Mayer (1997) shows in experiments how pictures and spoken text support comprehension when they are related to each other and presented close in space and time for students with low prior knowledge but high spatial cognitive abilities (for example efficient dealing with spatial relations, spatial visual tasks and orientation of objects in space).

Schnotz (2002) thinks the one-to-one mapping between the processing systems in the dual coding theory is questionable, because it is too general. He shows that there is not always mapping between different representations, even if they describe the same phenomenon. Therefore he does not agree with Mayer that pictures generally support comprehension.
5.2.1.2 The structured mapping hypothesis

Schnotz (2002) has another theory of how human brain process information. He calls it the structured mapping hypothesis. It has some similarities with the dual coding theory, but is more complex.

Spoken or written texts, logical expressions and mathematical equations are all examples of descriptive representations (Schnotz, 2002). This means a representation describing an object with symbol signs which are related to each other and the content so the relations in a described process are clear. Words (symbols) in a sentence for example are related to the content they represent by means of a convention. Verbs, nouns and prepositions come in an order that explain the relations between them and in the process they describe.

Pictures, animations and films can be said to be visual representations. They are what we call depictive, describing a process with iconic signs. We may understand some relations in a process from a depictive representation but there are no direct symbols for this. Depictive representations give us structural information about a phenomenon.

Figure 5.2 shows the organization of the structured mapping hypothesis. A person who reads a text first constructs a mental model of text surface representation, which leads to a propositional representation. From this a mental model of the text matter is created. Prior knowledge and cognitive schemata have a selective and organizing function here, helping to construct both the mental model and the propositional representation from the text surface structure. Since the mental model always is a depictive representation, construction of this implies a transition from descriptive to a depictive representation.

In picture comprehension a learner first creates, through visual perception, a visual image of the picture’s graphic display. This leads to a mental model, but also to a propositional representation of the subject matter. To understand a picture, not only perceive it, there must be propositional representations created. Also here, cognitive schema is selecting relevant information in the perceptual processing and organizes it in order to build a mental model. There must be elements in the perceived depictive picture which can be mapped onto the descriptive
propositional elements and depictive mental model elements to develop understanding of a picture.

Even though the dual coding theory and structured mapping hypothesis may look similar at a first glance they are different in some important parts. First, the dual coding makes no difference between processing written text and pictures. Second, the construction of a mental model in structured mapping hypothesis is much more than adding just one more kind of representation or code. The point is instead that propositional representations and mental models use different kind of principles and signs, which complement each other in a mapping system.

![Figure 5.2: The structured mapping hypothesis (From: Schnotz, 2002)](image)

5.2.1.3 Interferences in learning with text and pictures

The dual coding theory does not handle the question that a picture can visualize one object in different ways and that this affects the mental model in different ways, which must be said to be a weakness in the theory. It says that a picture is generally beneficial for comprehension.

Schnotz (2002) shows in experiments that pictures visualizing the same matter in different ways have different effects in understanding the subject. There may be no mapping between the depictive perceived representations and the descriptive mental elements which will have negative effects on the mental model construction. Schnotz (2002) let three groups of students, with similar prior knowledge and spatial and verbal cognitive abilities, do the same two text based tasks with help of different pictorial representations. One task was about time differences on earth and the other was about a circumnavigation. Group one had as help a flat map of earth where the time zones were marked (Figure 5.3). Group two had a circular diagram-liked picture of the globe “from above”, where the time zones and cities were marked (Figure 5.4). The third group had no picture at all.

It was documented how fast the three test groups did the two different tasks and also how well they solved them. The result showed that the flat map group did not do so well, compared to the
other groups, in the circumnavigation task but very well in the time difference task. The globe “from above” group had the lowest results in the time-difference task, but the highest in the circumnavigation task. The students having no picture help at all, solved the tasks quickest and had also the best overall result of all three groups.

Schnotz (2002) explains this by the different mental models the tasks was required and how well they mapped with the depictive external representations the students got as help. A circumnavigation task mapped better with a circular picture and vice versa.

Figure 5.3: Flat map picture (From: Schnotz, 2002)  
Figure 5.4: Globe “from above”(From: Schnotz, 2002)

5.2.1.4 Kozma and the impact of prior knowledge
Kozma (1991) has studied how different media like TV and computers have impact on learning. Also he based his idea in the dual coding theory. What he found though different experiments was that students are in need of different representations depending on what prior knowledge they have. Some students are not helped at all of pictures or computer programs since they can rely on prior knowledge and process text only representations very well. Other kind of representations will only make them more confused. A conclusion which in one way agrees with Schnotz’s that some pictorial representation can interfere with learning. He does not analyze different kind of pictorial representations though like Schnotz, but sticks to the dual coding theory and states that different learners need different kind of representations. Kozma (1991) also means that it is important that a chosen representation has a clear learning purpose. It is possible to see, use or hear a representation without understanding the learning point with it, which only will confuse the student. This will not activate the cognitive processes and not support comprehension.

5.2.2 Cognitive load theory (CLT)
When putting a presentation together is it also important to use a bearable load of information. How many representations can a teacher use in the same lecture without loading the students with too much fact?

Cognitive load theory (CLT) was developed in the 1980’s and can be used as a “tool” for reducing unnecessary or extraneous information in instructional material. It is based on the theory of a
dual coding processing system in the brain and says that humans have a limited working memory that can store less than nine items or elements of new information but can only work on about two to four at the same time (Sweller & van Merriënboer, 2005). If new information not is rehearsed and refreshed it will be lost in just 20 seconds. New information must be processed in working memory to construct schemata in long-time memory, which has unlimited capacity and stores a person's knowledge. Figure 5.5 shows the organization of the cognitive load theory.

A person may already have experience in a subject and have therefore already schema that incorporates the new elements of information. The cognitive load in a learning situation will be smaller for this person than for someone who does not have these experiences, since the schemata can be seen as one element of information and will highly reduce the load of the working memory. For example an expert chess player can only take a short look at a mid-game to know how to win it. His or her working memory is then unlimited because of all the help from the long-term memory or schemata. But a novel player, with no prior knowledge to help, has to organize and test all new information and is not able to deal with all possible ways of continue the game. The only way to learn and understand the game completely is to limit the information units to a number that can be processed simultaneously.

There are general ways a teacher can construct tasks and models to reduce the cognitive load for the students, making comprehension easier.

Figure 5.5: Cognitive load theory (From: Cooper, 1998)
5.2.2.1 Reduce cognitive load by Sweller & van Merriënboer

Sweller & van Merriënboer (2002) proposes that a goal-free task, where there is no right or wrong answers, reduces the cognitive load. The focus is on the problem and possible operators, which connect to the student's prior knowledge and therefore reduce the cognitive load. Sweller & van Merriënboer (2002) also proposes that one integrated picture with text is better than many smaller isolated pictures, since this reduces the work with mental integration of the information sources. He also means that a picture goes better with spoken explanatory text than written because this will use two, visual and auditory, processors in working memory. Information that can be understood without instructions should be taken away, to reduce unnecessary processing.

5.2.2.2 CLT by Mayer

To reduce the cognitive load it is not only necessary to reduce representations in all situations but sometimes more important to combine them in an efficient way. Mayer (2003) proposes that if the visual processing system is overloaded you can add verbal information to transfer some processing to the other cognitive channel. If both channels are overloaded it is needed to break down the material in segments, and first develop schemata about the basics before putting them together. Interesting but extraneous facts should be removed so they not disturb the important processes. Printed words are good to put close to corresponding picture so both are processed simultaneously. The teacher should also avoid to present identical streams of printed and spoken texts.

5.3 Development of RAIN presentation

In part 5.3 of the thesis the development of the school presentation will be described, how the content was chosen and structured. I will also explain how I used some particular pictures from the presentation and describe the interactive parts.

5.3.1 Content

The content in the presentation was chosen from articles, videos and documents about aerosol particles and RAIN project. Since I was new in the project in August 2011, I looked at the material with fresh eyes and everything that to me seemed like inspiring and interesting was picked out as good material for the presentation. Important pieces were the scientific meaning of the project and also the creative job the team had done their ideas and all the testing.

The RAIN presentation can be divided in two clear parts. The presentation can be seen in Appendix 1. The first part is about atmospheric aerosol particles and the other one is about the RAIN project. I wanted the students to get a clear picture of the scientific challenges of the experiment and the work of the team. I hoped this would make them engaged to the project and ask many questions and that they could imagine themselves as team members. To succeed with this I started the presentation with explaining what scientific challenges the RAIN experiment is dealing with and how the project is meaningful and important for us all. Before going on telling them about RAIN I let them have a few minutes to think for themselves how they would do to collect particles from 80 km.
5.3.1.1 The structure of the presentation

Table 5.1 shows the structure of the presentation. It starts about atmospheric aerosol particles, where they come from and what they are. Then it goes on explaining about the different layers of the atmosphere and how temperature and pressure vary through it. From this cloud formation is explained, how the particles have impact on that and how they in other ways affect earth, the climate, environment and our health. At this point the students get the question how they would have done to collect aerosol particles from 80 km, and what they think they would need to know for doing this. When they are finished and we have discussed their ideas, the presentation goes on with presenting the RAIN team, REXUS/BEXUS and the experiment. The FFU and RMU are described and some of the different parts of the experiment equipment the RAIN team developed. The presentation also shows how we test all parts we developed. Then we talk about how it is to work with the experts at ESA, DLR and SSC. In the end it is about the launch campaign in Kiruna and why this is a good place to launch rockets from. The very last slide tells what is coming out of our experiment and what kind of results we may have.

There is not room here to go through the whole presentation in details, but later in this chapter I explain how I thought when I picked out and put together some of the parts.

Table 5.1: Structure of presentation

<table>
<thead>
<tr>
<th>Themes in the presentation</th>
<th>Number of ppt slides</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerosol particles, what is that?</td>
<td>3</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>1</td>
</tr>
<tr>
<td>Particles impact on earth</td>
<td>6</td>
</tr>
<tr>
<td>How would you do?</td>
<td>1</td>
</tr>
<tr>
<td>This is RAIN</td>
<td>3</td>
</tr>
<tr>
<td>The experiment</td>
<td>5</td>
</tr>
<tr>
<td>Working in RAIN</td>
<td>2</td>
</tr>
<tr>
<td>Summary</td>
<td>2</td>
</tr>
</tbody>
</table>

5.3.1.2 Aerosol particles part

In the beginning of my work I started to read and collect information about aerosol particles. There was much information on the web, for example NASA’s website (www.nasa.com) and IPCC’s website (www.ipcc.ch). All the questions I had about aerosol particles, what they were and how they had impact on us, were written down and answered one by one. I got some articles from the PhD student Peggy Achtert at MISU about geo engineering (Crutzen, 2006), problems with aerosol collection techniques (Hedin, 2007) etc. She also answered some of my questions and told me very many exciting facts about aerosol particles, climate and meteorology while we were working together. For example she told me about big events that have had big impact on us.
and the climate, London smog, volcano Pinatobus enormous eruption 1991, and how the collapse of Sovjet Union in 1989 could rise the temperature in Europe.

You Tube was also a great help, for example I saw a very interesting presentation with scientists from the University of California in San Diego about atmospheric aerosol and impact on climate (UCSD-TV, 2008). I noticed that it was almost impossible to speak about atmospheric aerosols without having a little knowledge in meteorology and the atmosphere. Here I also had a great help of Peggy who lent me books and information about this.

To find suitable experiments having to do with aerosol particles I used You Tube and other websites and discussed my ideas with Peggy. The “cloud in the bottle experiment” was found on Steve Spanglers website (Spangler, 2009) and was developed further together with staff from Vetenskapens Hus.

5.3.1.2.1 Atmosphere model

To frame all scientific details in the presentation I thought it was needed to include some basic information about the atmosphere as well. To do this I chose a figure of the atmosphere which tells quite a lot about it, and gives a good overall picture (Figure 5.6). It contains information about the different layers and gives a feeling for how high 80 km really is. It also tells about how the temperature and pressure varies in the atmosphere. I think it is important that the students understand what kind of surroundings our experiment will fall through. It also helps to understand the complexity of the atmospheric chemistry for students with larger prior knowledge. When we met groups with low prior knowledge this picture felt a little too much the first time, like for them who were not familiar with pressure at all. But soon I discovered that the picture was still so simple so by just choosing other words explaining it even these students could follow. So I did not take it away at any presentation occasion. That was the strength with this picture I think. The atmosphere figure was also good to refer to in other pictures while holding the presentation.

![Image of Atmosphere Model](https://via.placeholder.com/150)

**Figure 5.6: Atmosphere model from presentation**
5.3.1.2.2 Atmospheric aerosol picture

The concept ‘atmospheric aerosol particles’ is definitely necessary to be explained in the presentation. But since it is new and quite complicated concept for many students, it is needed to be explained and used carefully. I thought they needed something real or familiar to relate to. So I gave some examples of aerosols and inserted a real picture of atmospheric aerosol taken from a satellite (**Figure 5.7**). Even if this not may give a proper explanation of the definition of the concept aerosol, the students get an idea about what atmospheric aerosol is I figured, based on schemata. I do not want them to get stuck on the definition every time I say the word because that is not important here. It is possible some students would have appreciated the proper definition, but when I met ambitious students I always told them that an aerosol is a suspension of liquid/solid particles in gas.

![Figure 5.7: Satellite picture of atmospheric aerosol over the Canadian Islands, used in presentation](image)

5.3.1.3 The RAIN project part

Information about RAIN project was collected from the website of the project, the blog, earlier presentations and through participation. I chose an old presentation about RAIN, took the slides I wanted to use and remade them so they suited my presentation. The RAIN project is so much more than just what is written down about it though. It has therefore also been very good listening to members of the team when they spoke about the work they did, the tests and the travels. The enthusiasm they can express is a very important piece in the presentation which is quite hard to catch by just reading documents about it. Examples of this is listening to the team member Patrick Magnusson when he told about the first brainstorming meeting the team had in the beginning of the project and when they went to ESA in Holland to present the project for the first time.

5.3.1.3.1 RAIN experiment picture

To explain how the experiment is going to be performed a picture of this was used (**Figure 5.8**). Just like the atmosphere figure it contains a lot of information and also an overall structure. There are some information parts missing though, like where the rocket is going after eject the FFU and how we collect separately samples during the fall. But this actually led to good questions. The picture gives direct a clear picture of the basics in the experiment and the students seem to easily read it off and can than give questions which make the presentation
formed also by them. This is the most important picture in the presentation I think, because the experiment is the core of it. If the students don’t understand the core, they will leave the room and wonder what the point was with everything.

There are ways to develop this model though, animate it for example. And also in some way include the rotating plate beneath it. The slide after this one in the presentation is about the FFU only, and to integrate these two pictures into a short film where you can both see it in a sequence and also stop to see details would be good I think.

Figure 5.8: The experiment picture from presentation

5.3.1.3.2 The launch campaign picture and video

The climax of the RAIN project is the launch in Kiruna. And this is best shown by pictures, to give a feeling about this big event in the project. Therefore I picked out pictures from last year KTH REXUS project SQUID, which was launched February 23, 2011 (Figure 5.9). Members from the SQUID team put together a launch video after finishing their project and parts of this video are shown in the RAIN presentation (SQUID, 2011). Some parts of the preparations are shown in the video and pictures of the launch, both from the rocket and the control room. This gives a really good understanding and feeling of what is coming up for the RAIN experiment in March. The video from space taken by the SQUID rocket, also gives understanding of the 80 km height and the power of the rocket. The last parts of the presentation are important for what the students remember afterwards, therefore I think this is good and powerful pictures to end with.
5.3.2 Interactive parts
After the presentation the students got some time for trying some experiments while they also could ask us questions. Two experiments were brought to all school visits and at Vetenskapens Hus we could also borrowed their microscopes to look at the target materials in the sample holders as an extra activity. At some schools where the time was not so tight, the students got a while thinking of how they would develop this kind of experiment as an activity.

5.3.2.1 Cloud in a bottle
The cloud in a bottle experiment is a model for how clouds are formed. Some rubbing alcohol is put into a plastic bottle. The air in the bottle is soon saturated with alcohol. The pressure is then increased as much as possible in the bottle with a hand pump. We do not have any pressure measure equipment, but in the end we cannot hold the plug anymore. We can follow the temperature rise in the bottle along the pressure rise with an IR thermometer. At the higher temperature more alcohol goes up in the air. When the plug in the bottle is pulled out and the pressure rapidly falls, so is the temperature. The alcohol molecules condense on the particles in the air and create a thick, white cloud (Figure 5.10). So, would this happen with clean gas (with no particles) in the bottle? Some dry ice is put in the alcohol in the bottle. The carbon dioxide is heavier than air and pushes it out and fill the bottle with clean gas after a while. When this is assumed to be done after a few minutes, the bottle is sealed with a plug and the pressure is increase in the bottle when the dry ice sublimes.

Again the temperature rise is controlled with the IR thermometer as the pressure increases. When the temperature and pressure are approximately the same...
as they were in the first part of the experiment, the plug is pulled out from the bottle and watch what happens! The cloud being formed is not at all as white and thick as in the first try. The thing I want to show with this experiment is: no particles, no fog.

5.3.2.2 Dry ice toys
Dry ice is needed for the cloud in the bottle experiment and therefore I have an excuse to bring this also as a toy for the students. It may not be very spectacular but still it is fun to play with, and they do get physical experience of sublimation while doing this. Pouring hot water on the “ice” creates a white, heavy cloud coming up from the bowl. With a help of a piece of fabric and soap water a soap film is put over the edges of the bowl. As the dry ice sublimes under the soap film, a big white bubble grows on the bowl (Figure 5.11). When it breaks the white cloud will fall down on the table.

It is also possible to rub a piece of dry ice hard against the table, which makes it flat on the underside. The dry ice is then hovering slightly on the gas under it and it looks like it has no friction against the table when pushing it around.

5.3.2.3 Microscopes
At Vetenskapens Hus we were allowed to borrow their light microscopes. Even though the magnification is lower than the SEM, it was possible to see soot particles and the fibers in glass fiber filter and bigger particles on the TEM grid. Next to the microscopes there were printed SEM pictures of the same things they saw in the microscopes.

5.3.2.4 How the students would do it
In the middle of the presentation, after telling about the scientific background and meaning of the whole project, the students got a while to think about how they would solve the task of collect particles from 80 km height. Because of short time, this activity took just a few minutes, which was a little too short. I think this is something that can be developed more and integrated with the other interactive parts.

5.4 Implementation
We met very different groups of students. They were different in age, prior knowledge and interests. It was also different to visit a school compared to let the school visit us (or Vetenskapens Hus). When the students come to Vetenskapens Hus they have quite high expectations, especially on the experiments they do. It is also only engaged teachers that bring their students there, which often leads to engaged students. When RAIN contacts a school and go there to meet the students, they often have no expectations at all.

Figure 5.11: Picture of dry ice bubble (From Sprangler, n.d)
5.4.1 Vetenskapens hus (Kärrtorps gymnasium, Kungsholmens gymnasium, Vittra på Södermalm)

Vetenskapens Hus is situated between KTH and Stockholms University and is run in collaboration of those. School students in all ages can come there with their teachers and try experiments and listen to presentations. We met three groups of science students there the 24th and 28th of October and 5th of December, from Kärrtorps gymnasium, Kungsholmens gymnasium and Vittra Södermalm. All schools are upper secondary schools and situated in Stockholm.

The students came there for a half day with space-theme. First they met us for about 90 minutes and after they did another activity at Vetenskapens Hus about rocket fuel.

Groups coming to Vetenskapens Hus often have engaged teachers and the students are often very interested. They had many questions about the presentation and details around it, like how a TEM-grid is manufactured and how the temperature in the thermosphere is measured.

5.4.2 Grindtorpsskolan

Grindtorpsskolan is a school with students in the age of 6 to 15 years old. It is situated in Alby, Botkyrka, south of Stockholm. RAIN was there for half a day November 9, 2011, and met all their 15 year olds in three groups. The students were just about to make their program choices for the upper secondary school (gymnasiet), starting in the autumn 2012 and many were quite confused about what to choose.

The presentation was held in Swedish because many of the students had difficulties with English. These were the first groups with younger students we met and the first presentation was a try how the material worked for them. For the second and third presentation we had learned that some parts had to be explained in another way than usual. For example some of the students did not know what pressure was and had never heard of the ozone layer. And not many knew where Kiruna is located. Things I on beforehand took for granted everyone knew about. It was also harder than usual to make them ask questions or answer ours.

They seemed to appreciate the experiments though and many filmed them with their cell phones.

5.4.3 Ross Tensta gymnasium

Ross Tensta gymnasium is an upper secondary school in Tensta, North West of Stockholm. They cooperate with Karolinska Institutet (KI) in Stockholm and have a special program for students interested in science. RAIN met a group of 20 students from the last year of this program at November 25, 2011. The presentation was partly held in English, which worked fine for the students and they had many questions about the RAIN project and about studies at KTH. These students have very high ambitions and many of them were planning for further studies at KTH or KI.

5.4.4 Värmdö gymnasium

Värmdö gymnasium is an upper secondary school that belongs to Värmdö eastern of Stockholm, but is situated at Gullmarsplan. RAIN met two groups there, totally about 50 science students at the 10th and 18th of November. The students were between 17 and 18 years old and was studying the IT and technology branch of the science program. In one of the groups there were five students doing their final project in a homemade balloon experiment and had questions about how to measure temperature and the presence of different particles in the atmosphere. We tried
to answer as many questions as possible and they thought the presentation was very inspiring for their smaller project.

5.4.5 John Bauer gymnasium Sundbyberg
The 16th and 20th of December 2011 we met two groups of totally 50 upper secondary school students from a hotel and restaurant program at John Bauer gymnasium in Sundbyberg. They were taking one compulsory course in nature science, and had just had an exam which among other things had included the atmosphere. The students were very prestige less and had many questions about the rocket and the experiment and referred many things in the presentation with things they already knew, like air pollutions over big cities for example. It was two very social groups we met at John Bauer and I think it was the school where we got the highest frequency of questions. It was also many students in each group, and not just a few, who were active with asking questions.

5.5 Assessment methods
I needed to know how the RAIN presentation was perceived by the students to understand if I had succeeded to make it inspiring and interesting. I also wanted to get an idea about their general attitude towards nature science, so I could understand how well it was perceived by students with different prior attitudes. For this two assessment methods were used, a questionnaire and group interviews.

5.5.1 Questionnaire
I made a questionnaire that I let some of the student fill in. It was students from Vetenskapens Hus and John Bauer gymnasium who were asked to answer some questions. The questionnaire is found in Appendix 2. Answerers were collected from both science and non-science students, since I assumed there could be a significant difference in general attitude between those two groups. Totally 83 students answered the questionnaire. The questions on the first page of the questionnaire were about their general opinion of the subject. On the second page there were questions about the RAIN presentation. On a scale from 1 to 5 (Likert scale) they would say how interesting they thought it was, if they learned something new, if they wanted to learn more and how difficult it was to understand. They would also with words answer what they thought about the experiments, what they would remember most from the presentation, if we could have done something better and if the presentation had made any kind of impact on their attitude towards science and technology.

5.5.2 Interviews
The interviews were supposed to support the questionnaire and give a better picture of the general attitudes and where they may come from. I met two groups, and one single student. All three interviews were recorded and transcript (Appendix 3). One group was science students and the other non-science students. The single student also came from a non-science program. The questions were about what they think is important in the career choices, what kind of jobs they relate with the subjects science and technology and if they know someone within the field. I tried to make the questions open and clear. My wish was that the students could discuss with each other and that different point of views would pop up.
5.6 Results from assessments
The students answering the questionnaire were generally positive about the presentation and the experiments. Totally there were 83 students answering the questionnaire, 47 science students and 36 non science students. They also got to answer some questions about their attitude to the subjects in general.

5.6.1 Students prior attitude
The first page in of the questionnaire was about their general attitude. The students in the science program thought science and technology were more fun and easy than the non-science students. Table 5.1 shows these attitudes.

Table 5.1: Students general attitude to science and technology

<table>
<thead>
<tr>
<th></th>
<th>Mean value science students (Max value)</th>
<th>Mean value non science students (Max value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>How fun is S&amp;T in school?</td>
<td>3.0 (5 = fun!)</td>
<td>2.5 (5 = fun!)</td>
</tr>
<tr>
<td>How fun is S&amp;T “outside school”?</td>
<td>3.7 (5 = fun!)</td>
<td>2.6 (5 = fun!)</td>
</tr>
<tr>
<td>How difficult is it with S&amp;T?</td>
<td>3.2 (5 = hard)</td>
<td>3.5 (5 = hard)</td>
</tr>
<tr>
<td>Are you considering a career in the S&amp;T field?</td>
<td>2.8 (5 = yes!)</td>
<td>1.9 (5 = yes!)</td>
</tr>
</tbody>
</table>

5.6.2 Likert scale questions in the questionnaire
The second page in the questionnaire was about the presentation. It started with four questions answered with a Likert scale. Table 5.2 shows the results of these questions.

Table 5.2: Students answers about presentation

<table>
<thead>
<tr>
<th></th>
<th>Mean value science students (Max value)</th>
<th>Mean value non science students (Max value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>How interesting was it?</td>
<td>4.3 (5)</td>
<td>3.6 (5)</td>
</tr>
<tr>
<td>Did you learn</td>
<td>3.8 (5)</td>
<td>3.3 (5)</td>
</tr>
</tbody>
</table>
many new things?

<table>
<thead>
<tr>
<th>Would you like to learn more?</th>
<th>Difficulty level</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.7 (5)</td>
<td>1.6 (5=hard)</td>
</tr>
<tr>
<td>2.5 (5)</td>
<td>2.5 (5=hard)</td>
</tr>
</tbody>
</table>

5.6.3 Open questions in the questionnaire

The last part of the questionnaire was open questions about the presentation and experiments. I asked them if there were any difficult parts, how they liked the experiments, what they would remember most, what we could have done better and if the presentation had had any impact on their attitude to nature science and technology.

5.6.3.1 Difficult parts in the presentation

Most of the students found the presentation easy to understand and had not written any comments about difficult parts. Some mentioned the language though and the many difficult words and shortenings of words. In the presentations partly held in English (at Vetenskapens Hus), there were comments on difficult English. Examples of comments were:

"Words"

"Explain all shortenings more carefully"

"Many difficult words"

"Some parts of the presentation were in advanced english"

"Easy to understand! A very good presentation!"

"Quite many new things, hard to understand everything new"

5.6.3.2 The experiments

The experiments were appreciated by the students. There was a wide mix of comments about those, most of them positive. Some students though the experiments were fun but not so meaningful though or the opposite. Some also seemed to miss a clear relation between the project and the experiments, especially those students who we met at Vetenskapens Hus. They expected probably experiments with more focus on learning, not only for fun. Examples of comments are:

"The pressure experiment was both fun and interesting!"

"Absolutely okay. Not so relevant for project RAIN, more general for pressure and temperature"

"They were really interesting! The most fun was the dry ice!"

"The cloud in the bottle was fun!"

"The one where we created clouds in a bottle with and without particles. It made me understand!"
"Yes, it was very fun!"

"No clear connection to RAIN"

5.6.3.3 *What the students would remember most*

On the question what they would remember most from the presentation, there were all kind of answers. Things returning several times were the film sequences of the ejection test and launch of SQUID. Also the experiments and "how the particles affect us" seemed to be things they would remember. Examples of comments are:

"Two sensors ejected from the rocket"

"Particles in the atmosphere"

"The impact the particles have on us"

"The videos of the FFU falling"

"The probes and the tests that were done with them"

"What they wanted to do"

"The ice..."

"The experiments"

5.6.3.4 *What we could have done better*

When it comes to what we could have done better, there were comments on the lengths of the presentation. It could be a bit shorter. This comment was most frequent from the students we met at Vetenskapens Hus who had a bit longer presentation, one hour. Some students also wanted the experiments to be clearer connected with the project. Examples of comments are:

"The experiments should be before the presentation, so we get the explanation after"

"A bit more relevant experiments"

"Explain all abbreviations"

"More experiment"

"It could have been a bit shorter"

"Less time listen, more time for experiments"

5.6.3.5 *Impact on attitudes*

The last open question was if the presentation had had any impact on their attitude to science and technology, and if, what kind of impact. *Table 5.4* shows how many that expressed positive or no impact on their attitude. Many of the science students gave very positive answers here. No one expressed any kind of negative impact. Examples of the comments are:

"Yes, it grows because this was inspiring"
"It seems more fun than I thought before"

"Interesting to see different science areas combined"

"Yes, definitely. Gave motivation for further studies at KTH and the project seems very interesting!"

"I was already interested"

"Not quite. I have never been interested in science. But cool project!"

Table 5.4: Students answer on what impact the presentation had on their attitude to the subjects

<table>
<thead>
<tr>
<th></th>
<th>Science students</th>
<th>Non science students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive impact</td>
<td>34</td>
<td>12</td>
</tr>
<tr>
<td>Negative impact</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>No impact</td>
<td>14</td>
<td>24</td>
</tr>
</tbody>
</table>

5.6.4 Interview results

In the first two interviews I met students from the hotel and restaurant program. This interview showed that they had quite poor understanding of what an engineer or scientist actually does. No one had close friends or relatives working within the field but all knew someone close who worked with the same thing as they dreamed about. The main reasons for them to choose the hotel and restaurant education were that it was a fun and interesting program. But also, it was a practical program and easy for them who did not like to read and study from books a lot. It would give them job directly after they had graduated and it did not close any doors for them who may want to continue at the university later in life. They all found science as a very hard subject, important for the society but not for them in everyday life. Transcripts of the interviews are found in Appendix 3.

In the third interview I met students from the science program. They all had the dream to continue within the science field and all of them knew someone close who had the same profession as they dreamed about. Status was important for them in their career choice and they thought the job they wanted was going to give them this. But it was also important to have an interesting job. They were all working hard with their studies and thought that an education like that needs to lead to something well paid and with high status, otherwise all the hard work would be for nothing.

The main difference between the science and non-science students was in the relationship to the subject. The science students knew close people who worked within the field. That the non-science students did not. They had not the same insight in the area as the science students had. The non-science students also expressed that science was a very difficult subject, almost not understandable at all. The science students said they were in a program which was requiring a lot of hard work, but their goal for the future made it worth it.
6 Discussion

6.1 Reflections of the presentation
In chapter five I presented some learning theories. They were dual coding theory, structured mapping hypothesis and cognitive load. I was also discussing the ROSE study which gives a picture of what students generally find interesting within the field science and technology. When I first put the RAIN presentation together I did not let these theories lead me, but did it from my own idea and taste. In this first part of chapter six I will look at some parts of the presentation from the perspective of those learning theories and the ROSE study.

6.1.1 Interferences in learning from different representations
It can be hard to say how well the different representations in the presentation supported or interfered with each other since there is no other combinations of representations to compare with. But the questionnaire results show that most of the students found it quite easy to understand and that means no large interferences. Kozma (1991) proposes that students with different prior knowledge are in need of different representations. The RAIN presentation was not changed for the different groups, but it was differently used depending on the prior knowledge of the group. Different details were mentioned and the facts were described more or less deep. So the verbal representations differed between the presentations. This was extra clear during the three presentations at Grindtorpsskolan where the students were younger and where many had a poor prior knowledge. Many things in the presentation had to be explained in a completely different way than it used to be.

6.1.2 Cognitive load of the presentation
The presentation contains a lot of facts, models, pictures and films so at a first glance one may think it will cause a cognitive overload for the students. This might depend on the prior knowledge of the students though. The power point presentation does not contain much text, but quite many pictures or photos. The photos will activate experiences and schemata the students may have, which will reduce the cognitive load (Sweller & van Merriënboer, 2005). However, this will only happen if they have experiences within the subject. Since the questionnaire showed that the difficulty level of the presentation was rather low and the interest level was rather high for the science students, my conclusion must be that the cognitive load of the presentation was not so heavy for them. The interviews and questionnaire also showed that they had better insight and general attitude to the subject than the non-science students. The latter group found it more difficult and less interesting which partly could be because the cognitive load for them was greater since they not had so much knowledge within the science field.

The ejection test film and the film from the SQUID experiment gave a real world understanding of the work the RAIN team been doing and about the flight, which might reduce the cognitive load. This would especially be true for the students who not had a big prior knowledge in how to work in the science field. The open question how they would develop this experiment could also be a cognitive load reducer according to Sweller & van Merriënboer (2005), since there are no “right answers” to it.

There are quite many interesting facts which may be unnecessary in the presentation though, according to Mayer (2003) this raises the cognitive load. One example is the fact that cooking
over open fire is the biggest pollution source in India. It is not written in text, but it is a picture of a man doing this on the same slide as pictures of other pollution sources. There is a balance between making it interesting and colorful and not overloading it with facts. I reduced the load of unnecessary information several times before I held the first presentation. One comment which returned a couple of times in the questionnaire was that the presentation could have been a bit shorter; this I would have succeed with by taking away some more extraneous facts. On the other hand, many particular extraneous facts came up in the questionnaire as things the students would remember most from the presentation. Therefore I am not sure it would have been much better if I took them away.

The cloud in the bottle experiment often felt a bit too heavy. The students seem to find it amusing with the cloud according to the questionnaire, but the time felt often too short to explain the experiment for them. That was facts no one really had space for after the presentation. If the experiment would have been simpler and more connected to the overall message of the presentation, it might have been easier to grasp. Now it was connected to a part of the beginning of the presentation, too far away in time. The dry ice experiment was not very connected to RAIN, but the goal-free feeling the students got from it may be cognitive load reducing. It was appreciated of both science and non-science students.

### 6.1.3 Interest of content

According to the questionnaire results both science and non-science students prefer science “outside of school” rather than the school subject. I assume that means they like popular science more than what they learn in school. This would then support the results from ROSE, that space and exciting scientific discoveries are areas students prefer to learn about (Sjöberg, 2005). A project like RAIN can be a good example of exciting science, presented from that point of view. Environment and climate questions are hot subjects in media and they have impact on all life on earth. This can again be connected to the ROSE study since ROSE shows that subjects related to the health of the students are popular topics.

Both science and non-science students seem to generally find the presentation interesting, even though the science students found it significant more interesting. According to ROSE there are no differences in what topics within the science field students from different programs find interesting. The general opinion about the whole science field differs though according to the questionnaire, which might have been the reason why the non-science students found the RAIN presentation less interesting. Also the cognitive load, which was greater for the non-science students, could have made it harder to appreciate for them.

### 6.1.4 Picture of the science or technology profession

The hotel and restaurants students I talked with in the interviews had very little insight in engineering. I got following answer on my question what kind of professions they related to science and technology from a female student:

*Student: I don’t know (hahah)! Well, science has always been difficult for me, always. But here in the second grade I passed the science course for the first time. Now it is fairly ok and I can understand that we need some knowledge in science. Technology has always been fun for me, like build things you know… But I do not know what kind of profession that would be, that is not information I have ever got. Not in school. They say like this: you need to know science. It is not like:
science, yes, fun! There is no information about what I can use it for, if I would be in the science program or so.

When I asked the same student if she knew someone who work within the science or technology field she answered no, but later in the interview when we were talking about teachers she said:

Student: And technology has always been fun. And we had woodwork in school. Build things after school that was fun, when I was younger.

Me: Did you have a good woodwork teacher?

Student: Yes, it was my aunts’ husband. My whole family is creative people who are building things.

The student says she does not know what an engineer does and she does not know anyone who works as this. It is not something she immediately relates to building. To make a drawing of something and then build it is not something a technician does, that is something creative that craftsmen are doing. And this is understandable, how often is the handcraft room used in math, technology or science education? Not so often is my apprehension, even if there are many applications for those subjects in for example textile and wood works.

But it was not only the hotel and restaurant students who had little insight in the science and technology professions. Even though the science students wanted to become engineers or medical doctors they wanted it because of the status and money which comes with the job, even though it was most important that the job seemed interesting. They knew people in these professions but were very unspecific about what they liked with these kinds of jobs. The hotel and restaurant students, who often had some work experience, seemed to be much more clear about why their dream profession would suite them. One student, who dreamed about being a medical doctor, said:

Student: I wanted to be a football player when I was a kid. But that has changed. I will work with something within medicine, I am sure about that. But not scientist, I do not want to be a scientist. After two weeks at KI, never… (he shakes his head)

Me: What was wrong with the scientists at KI?

Student: No, it was just sitting in front of a computer. She said she could sit there for fourteen hours per day at KI and just analyzing things, which is not my thing…

The other students in this group were nodding understanding when this was said. To analyze or do administrative tasks in front of the computer is nowadays a big part in almost all kind of knowledge work also for medical doctors, lawyers and engineers. All scientists are not sitting by the computer 14 hours per day either, but could for example stand in a lab quite a lot. I got the feeling these students had not so much insight in the professions they dreamed about. They were not so specific when they described why they wanted them, like the hotel and restaurant students were.

I interviewed only ten students and they are of course not at all representative for all the young people in Sweden. But what these students need, and what I think many other students also need, is concrete information about what different professions actually do. They need to see the alternatives to be able to create specific wishes for their career choices just like the debate article in Göteborgs Posten which I mentioned in the introduction proposed. This is something a project
like RAIN can offer, at least as a concrete example of higher technology education. Upper secondary school students have already done some important choices though and this would be an incitement to also meet younger students as well.

6.2 Reflections of the assessments methods
I chose to have two different assessments methods since it could be hard to understand the differences in attitudes to the science subject from only a questionnaire. The answers from the questionnaire did give a good picture of the quality of the presentation though.

It was quite difficult to draw any straight conclusions from the open questions in the questionnaire, even if those answers were the most exciting and informative for me who held the presentation. It may have been good to make a couple of extra more Likert scale questions about the experiments for example, to get a clearer picture of how the students liked them.

The interviews did not of course give any general answers of what Swedish youth think about science and technology. They give examples of some student attitudes which we can discuss around. Me as an interviewer, I also made my interpretation of what the students answered and was also the question constructor. However, the interview does support the questionnaire and gives examples of why the non-science students did not like the presentation as much as the science students did.

6.3 Reflections of the aerosol collection experiment
In the aerosol collection experiment we did succeed to collect and analyze particles in the size of approximately 100 nm to 100 µm. The small meteoric smoke particles we may find in the mesosphere will be smaller, perhaps only 10 nm, and can be tricky to analyze in the SEM. The biggest particles we are likely to find in the stratosphere are about 1 µm, those could be captured by both the gel and grid.

6.3.1 The different target materials
On the glass fiber filters we found large particles, which we also had assumed in advance. Smaller particles will go through the holes in the fiber net and not very often be visible in the SEM. Big particles around 100 µm, are not likely to find in the middle atmosphere.

On the grids we were mostly looking for small particles, which also were caught, but they were difficult to discover and to analyze. The grids were also very hard to handle and easy to damage while loading them. But they could also be good for catching a bit bigger particles around 1 µm, since we found some of those on grid number five. We could not do a x-ray analysis of the particles we found on the grids because of the strong aluminum background. It would have been interesting to see if it was the same kind of particles as we saw in the gel. If a certain particle is interesting in the post experiment analysis, the grid can be moved to another sample holder with no aluminum background and be analyzed in that.

The gel was definitely a positive surprise! After some not so successful SEM sessions trying to get focus on the gel surface we got some really good pictures after spraying the surface with a thin layer of gold. Particles in a wide size range could be observed and analyzed, from 100 nm to at least 50 µm. It is of course harder to navigate on gel samples than on the grid samples, but they are easier to handle than the grids. We did not look at any clean gel samples, so we do not know if we contaminate the gel when we for example handle it outside the clean room to put it in the oven while preparing it. Since we did not have any big contaminations on the filter or grids from
loading, probably the gel is clean too. But the gel preparations include some steps the other materials not do, so we cannot be completely sure.

### 6.3.2 Leakage of particles

No big leak of particles could either be observed on the only not exposed grid that was analyzed in the car test. The contamination test showed aluminum particles, 10 µm, and a fiber, 200 µm, on the glass fiber filter. The aluminum particles come surely from the FFU and the fiber could come from the teflon sealing that is situated on the aerosol collection plate lid and reduces the friction between this and the base plate. But the fiber could also come from somewhere else, the clothes of the person preparing the sample for example. The really small particles, 200 nm or less, were very hard to distinguish with SEM though and we only analyzed a small area of the grid sample. The before and after pictures can also sometimes be difficult to compare, the brightness of the pictures is varying and it can be difficult to see the small particles. Therefore I would say we cannot be totally sure that the FFU does not leak in any small particles. As the FFU falls there might be particles collected outside on the aluminum base plate. We do not know if these particles can be "pushed down" into samples exposed on lower altitudes. If same particles are found in suspiciously big height range in post experiment analysis this risk might be regarded.

### 6.3.3 Test methodology

It takes a lot of time to operate the SEM. The small samples become like football fields in the microscope and patience is needed to find the tiny particles. The method of analyzing four squares of every grid and compare these pictures with new ones taken after the car test was necessary for finding the smallest particles. But it is important that the pictures are comparable of course, in some cases the before and after pictures were taken with different detectors. Since the higher detector (SEI) gives a stronger signal than the lower (LEI), some particles that were observed with SEI became invisible with LEI. This gives pictures that are not comparable. We should have put more effort on getting better comparable pictures, maybe two pictures of every square taken with the two different detectors. We should also have taken a picture of the whole grid so we could see any big damages in the film. This was not done on all the grids in the test. The holes we saw were found by accident while navigating around with the SEM on the samples. Since we did not look for any bigger particles on the grids until the analysis of the last one, we did not find any big particles until then of course. The grids may be good for catching particles that we do not see in the gel or on the filters. Since we do not know that we might have looked for bigger particles from the beginning also on the grids.

### 6.3.4 The chemical composition of the particles

The crystalline-looking particles containing Cl, Na, K, and F are surely from road salt. The car test was performed in November and the big roads were surely salted by then. We also found particles containing C, O and Ca. This might be CaCO₃, calcium carbonate, which is a mineral that can be used as filler in asphalt. Many particles contained a lot of C, which could be soot particles or organic compounds from the asphalt. We did not find any trace of sulfur which would be likely to find in oil products. The clusters of particles that we found in the gel could have been small water droplets with particles hitting the sample and leaving the particles in clusters on the surface.
7 Conclusions

7.1 One-occasional presentation
Here follow the conclusions for how a “one-occasional presentation” should be structured for engaging more students in the science and technology subjects. The conclusions are based on both the literature studies of learning theories and empiric results from questionnaire and interviews.

7.1.1 The structure of presentation
A school presentation should not be more than 45 minutes listening for the students. The messages should be clear and extraneous facts which are not closely related to the “main path” of the presentation should be removed. Pictures, photos and films of the content which clearly support the comprehension of the material and make the students relate to own experiences are very good to use. There should not be too much information from many different representations on for example one power point slide though. If there is an informative picture, no explaining text is needed but this is rather done verbally. Depending on prior knowledge of the listeners the representations should be adapted to suit them. Therefore it is good to use pictorial representations which is easy to understand for many and then can be verbally developed for groups with larger prior knowledge. Words and abbreviations which could be unknown for the students must be explained, especially if the presentation is held in English.

7.1.2 Content of presentation and interactive parts
The content should be something that is thrilling and new, something the scientists do not know everything about yet. Space science is a good example of this. It is good to relate the content to how it has impact on the student's lives and health. It is also good to put focus on concrete and creative work within the science and technology field.

The interactive parts are definitely important since many students think it is fun with some practical work or discussions and not only listening. Since it also is a representation of something in the presentation, it can support comprehension and give new or connect to prior experiences. There is a risk that it does not connect to the presentation in a good way or that it causes a cognitive overload with too much facts. For a “one-occasional presentation” it is therefore more important that the interactive parts are free and fun than informative. It is good with something that the students can do on their own, build or try “hands on”. Since “open experiments” or questions (with no right answer or goal) are reducing the cognitive load, it is good with these kinds of tasks. A clear connection to the presentation is however needed to make it meaningful and the theories of the science behind must be explained for the students with a larger prior knowledge. In this way an experiment can be appreciated of students in all knowledge levels.

7.2 Aerosol collection experiment
Here follow the conclusions from the results of the aerosol collection experiments.

7.2.1 The experiment
The FFU can contaminate the samples with aluminum particles and maybe fibers from the teflon sealing on the aerosol collection plate lid. But the contamination does not seem to be very big
with many particles. It does not seem like the FFU leaks in any particles from the outside, but we cannot be absolutely sure about the smallest particles less than 200 nm.

Since we succeeded to collect aerosol particles from the air along the road, and we learned a lot about the analyzing process, the experiment must be said to be very successful with clear results. The aerosol collection experiment says not so much about how it will work during the real experiment in space though, since the conditions for this are completely different.

7.2.2 The results
On the TEM grids, particles in the size range 100 nm to 10 µm can be found. They cannot be chemically analyzed in the RAIN sample holders, but must be moved to other sample holders if this is wanted.

On the glass fiber filter big particles larger than 5 µm can be observed. It is possible to make a chemical analysis of the sample.

The gel samples need to be sprayed with gold before putting them in to the SEM. On the gel it is possible to observe particles from 100 nm up to 100 µm and to do chemical analysis of them.

We found particles that can be soot and minerals from the asphalt. Also road salt was surely found.
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Appendix 1 Presentation

Hi, we are RAIN!

Today:
- Talk atmosphere
- Get to know project RAIN
- Try some cloudy experiments

Hej vi är RAIN!

Today:
- Talk atmosphere
- Get to know project RAIN
- Try some cloudy experiments

How would you do to take samples of something 80 km up in the atmosphere?
Different types of particles

For example, volcano ash, pollen, sea salt, and soot. The smallest are just a few nanometers (≈ 10^{-9} m ≈ size of a virus). The largest are several micrometers (≈ 10^{-6} m ≈ diameter of a hair).

Atmospheric aerosol = liquid/solid particles in the air

Examples of aerosols:
Smoke = Solid particles in gas
Fog = Liquid particles in gas
To understand how aerosol particles are important to life on earth, we need to know some about the atmosphere.

Water molecules condense on particles in the atmosphere and clouds are created!

Atmospheric aerosol particles = kondensation nuclei

If there were no particles in the atmosphere, there wouldn’t be clouds as we are used to! No particles no fog

Clouds and particles scatter sunlight, cooling the earth.
In 1989 there were a significant temperature rise in Europe, why?

Same particles cooling the earth, make acid rain, destroy ozone and hurt people!

Karolinska Institutet estimates that 5300 people die every year in Sweden of illnesses caused of aerosol particles.

The particles can give us hart and lung diseases, and hurt our genes!
Local emissions lead to global problems and local effects on the other side of earth!

**How would you do it?**

How do we reach to 80 km?

Kreativitet

How to make aerosol particles stick to the sample holders?

What materials do we need to build it?

How do we find the experiment after landing?

Everybody do a piece of the project

There are no “right or wrong”

And how do we know it’s going to work?

**RAIN**

- Rocket deployed Atmospheric probes conducting
  Independent measurements in Northern Sweden
- Want to develop an effective and reliable technology for aerosol measurements in the middle atmosphere
Who are we?

- 16 team members
- REXUS/BEXUS team
- KTH and Stockholms University
- 7 countries represented
- Meteorological Scientists
- Mechanical Engineers
- Electrical Engineers
- Mechatronics Engineers
- Engineering Physics
- Chemistry Engineer

How are we doing this?

1. $t=0$ sec, $h=0$km. Rocket launch.
2. $t=+63$sec, $h=57$km. Probe ejection.
3. $t=+145$s, $h=60$km. Apogee
4. $h=60$km. Collection phase begins, turntables begin rotating.
5. $h=0$km. Parachute deployment.
6. $t=+16$min, $h=0$km. Landing.
Probe = FFU

The Rocket Mounted Unit (RMU)

- Holds the FFU:s during launch
- Ejects the FFU:s
- Filming launch and ejection

The students have made everything!
Many, many tests!
- Parachute deployment
- Drop test (from a weather balloon)
- Ejection tests
- Vibration test
- Thermal testing
- Assembly inspections

Work with ESA, DLR, SSC

Launch Campaign
- 2 weeks in Kiruna
- March 2012
- Lots of work and fun!
  Video launch 2011
Why Kiruna?

What’s coming out of our experiment?

- Do the aerosol collection technology work?
- 2 profiles of atmospheric aerosols
- The analysis will be done with a Scanning Electron Microscope (SEM)
- Help us to understand the complex chemistry in the atmosphere

Now: Cloudy experiments!

- How and why are there clouds?
- Dry ice Clouds

And don’t forget to follow RAIN at our website and blog: www.rainexperiment.se
Appendix 2 Questionnaire

1.) Hur kul tycker du att det är med naturvetenskap och teknik?

I skolan:

Trist! 1 2 3 4 5 Superkul!

Övrigt intresse:

Trist! 1 2 3 4 5 Superkul!

2.) Hur svårt/lätt tycker du att det är med naturvetenskap och teknik?

Jättelätt! 1 2 3 4 5 Jättesvårt!

3.) Skulle du kunna tänka dig att studera eller arbeta inom det naturvetenskapliga eller tekniska området?

Nej absolut inte! 1 2 3 4 5 Ja absolut!

Tack för din hjälp!

1.) Var dagens RAIN presentation intressant?

Inte alls 1 2 3 4 5 Ja absolut!

2.) Lärde du dig mycket nya saker?

Inte alls 1 2 3 4 5 Ja absolut!

3.) Skulle du vilja lära dig mer om atmosfären eller raketforskning?

Nej absolut inte! 1 2 3 4 5 Ja absolut!

4.) Var det lätt/svårt att förstå presentationen?
Jätteåret! 1 2 3 4 5 Jättesvårt!

Om det var svårt, vad var svårast?

5.) Kändes experimenten meningsfulla/roliga?

6.) Vad kommer du minnas mest från presentationen om RAIN?

7.) Vad kan vi göra bättre?

8.) Har presentation påverkat ditt intresse för naturvetenskap och teknik på något sätt? Hur då i så fall?

9.) Övriga kommentarer:
Appendix 3 Interview transcripts

Interview 1 (non-science students)

Jag: Om du tänker på din framtida karriär, vad är då viktigt när du gör val inför det? Vad det gäller yrke eller studier eller så.

Elev: Vad som är viktigt?

Jag: Ja.

Elev: Att jag kan mycket innan. Att jag har fått mycket information, det är nog viktigt för mig. Jag tycker inte det är så viktigt... alltså, nu efter trean så tror jag att det viktigaste är väl om man kan få jobb och så. Hur mycket jag kan.

Jag: Ok. Så du vill ha mycket kunskap i ämnet?

Elev: Ja. För då blir man mer redo för jobbet.

Jag: Ja, ok. Så... men. År det det enda, eller finns det fler faktorer som du tycker är viktiga?

Elev: Inte vad jag kommer på nu ivilketfall.

Jag: Inget du kommer på nu? Nej, men det är jättebra. Om jag säger naturkunskap och teknik då, vad tänker du då på yrken?


Jag: Tyckte du det var så redan på grundskolan?

Elev: Ja, jag har alltid haft svårt för de här långa orden, förkortningarna. Men det gick igenom till slut efter fyra omprov.

Jag: Det var ju jättebra för dig. Man kan ju inte välja bort naturkunskap, det är ju ett obligatoriskt ämne.

Elev: Ja.

Jag: Men med andra ord så tycker inte du att du har... för du sa på första frågan där att du vill ha kunskap om det du ska jobba med, så då tycker inte du att du har så mycket sån kunskap om naturvetenskap för att vilja jobba eller studera det?

Elev: Neeej. Naturkunskap har jag inte så mycket kunskaper i.
Jag: Vad är ditt drömyrke då?


Jag: Men gå hotell och restaurang skola i London?


Jag: Så ni har gjort lite praktik och så alltså?

Elev: Ja, förra året men det var i kök. Jag har aldrig gjort något hotell, det kommer i vår.

Jag: Känner du någon som har den här typen av jobb?

Elev: Jo men, min kusins pojkvän, han jobbar med hotell management på Järva Krog. Han har jobbat åtta år på det hotell så han kan.

Jag: Känner du någon som arbetar inom natur eller teknik området?

Elev: Nej. Min andra kusin Marit skulle studera... men hoppade av, det var för jobbigt.

Jag: Jo men det kräver mycket jobb de där utbildningarna.

Elev: Hon blev SYV istället.

Jag: Det är ju ett fantastiskt roligt jobb också...

Elev: Men naturvetenskap har blivit roligare... och lite mer lätt.

Jag: Vad är skillnaden då, från förr.. finns det någon skillnad?

Elev: Lärarna.

Jag: Är det lärarna?

Elev: Ja, min förra lärare var mer, hur ska jag säga det... ville inte hjälpa till. Alltså grundskolans lärare är väldigt under... gymnasielärare är mera nivå tycker jag. Hon hjälper till när man behöver och man förstår och sånt. Så var det inte förut, man fick bara arbeta av sig själv och det

Jag: Men va roligt att det blivit bättre!

Elev: Och teknik har ju alltid varit roligt. Och vi hade ju slöjd. Bygga saker efter skolan, det var kul, när man var yngre.

Jag: Hade ni bra slöjd lärare?

Elev: Ja, det var min mosters man. Hela min släkt är personer som bygger och skapar och så.

Jag: Va bra, tack nu har jag nog fått vad jag behöver!

**Intervju 2, JB.**

Jag: Jag tänkte att ni skulle få lista viktiga faktorer då ni gör karriär val. Då det gäller studier eller yrke, vad är viktigt när man väljer?

Elev 1: Att göra något man tycker är roligt.

Elev2: Det man trivs med.

Elev3: Det man är intresserad i.

Elev4: Något man vill fortsätta med också. Alltså inte bara jobba fem år och sen byta till något helt annat yrke.

Jag: Så det är viktigt att välja rätt från början?

Elev4: Ja, man borde fortsätta med det, för man utvecklas ju inom det yrket.

Elev3: Ja men, det jag har märkt är att folk väljer gymnasium, själva linjen, som hotell och restaurang för det tror det är så enkelt. Men sen när de börjar så vill de byta linje.

Jag: För att det inte är så enkelt, eller?


Elev1: Jag tycker man ska göra något man tycker är roligt för stunden, för det är då man kommer trivas som bäst och sen om du ändrar dig så kan du ju gå vidare.

Jag: Men det låter som ni är ganska överens om att det ska vara roligt. Finns det andra faktorer? Tänker ni på något konkret i jobb situationen, utbud av jobb i framtiden inom området eller så andra praktiska saker?

Elev4: Inom hotell och restaurang är det ett plus att kan man det så finns alltid jobb. Man kan plugga vidare och ha det som extra jobb. För det är ganska enkelt att få jobb inom restaurang

Elev 1: Sen så, det behövs ju alltid bra kockar. Det är ju något som går åt, i arbete.
Elev2: Det finns alltid lediga jobb.

Jag: Hur tänker ni om naturvetenskapliga och tekniska utbildningar? Nu har ni inte valt den inriktningen på gymnasiet, men vad blir man när man utbildar sig där? Vilka yrken tänker ni på?
Elev3: Alltså, biologi tänker jag på. Proffessor.
Elev1: Sen så civilingenjör, läkare, och så där.

Jag: Tror ni det finns några bra anledningar att välja sådana yrken?
Elev1: Att det behövs för framtiden. Vi behöver ju forskare och så så vi kan forska om framtiden... det är ju viktigt. Och läkare behövs det också mycket av.
Jag: Vad har ni tyckt om den tekniska och naturvetenskapliga utbildningen i skolan hittills?

Jag: Vad kan det bero på, är det ämnet i sig eller är det skolan som inte kan göra sitt jobb?

Elev2: Det beror ju på vilken lärare man har egentligen.

Elev4: Det här är förro provet, jag fick typ 0 av 40!
Jag: Men hade du pluggat någonting?
Elev4: Nej. Men jag skulle ändå inte begripa någonting.

Jag: Det tror jag nog, om du bara hade pluggat lite. Vad tycker ni andra om skolämnet?
Elev2: Det är svårt. Vi hade ingen NO de första åren, så nu i trean är det svårt.

Jag: Känner ni någon som jobbar inom det tekniska eller naturvetenskapliga området?
Elev3: Jag har en kompis som går på KTH, jag vet inte vilken utbildning, men det är lite natur och sådär.

Elev4: Min syrras kompis ska studera vidare till typ professor nånting.
Jag: Känner ni andra någon?

Elev2: Ingen jag kommer på just nu.
Elev1: Jag har en kompis pappa som är läkare.

Jag: Vad vill ni bli då?

Elev4: Polis.

Elev2: Jag vill bli kock.

Elev1: Jag vill också bli kock. Men sen så får vi se vad som händer.

Jag: nej precis, det är ju ändå många som har två eller fler olika karriärer nu för tiden. Man utbildar sig och byten sen bana.


Jag: Hur kom det sig att du valde hotell och restaurang då?


Jag: de här yrkena ni vill bli, känner ni någon som jobbar inom det yrket?

Alla: ja.


Jag: Känner du någon kock?

Elev1: Ja, det gör jag

Jag: Och känner du någon fotograf?

Elev3: Ja, jag känner en fotograf som jobbar på en tidning.

Jag: Vad är det som lockar med de yrkena ni vill bli?


Jag: Hur tänker ni andra då?

Elev4: Skolan låg fem minuter hemifrån.

Elev1: Jag tänkte att jag ville läsa något intressant och roligt. Och så är det så många som läser sam och ekonomi och så och de vet liksom inte fortfarande vad de vill göra när de gått ut gymnasiet. Och det är skönt att ha ett yrke klart efter skolan.
Elev4: Men det är ju ganska enkelt, det är ju bara tre år. Andra program måste man ju plugga vidare, sam och natur och så.

Jag: Men elev1, har du tänkt att plugga vidare sen?

Elev1: Jag har tänkt vara kock så länge jag orkar för det är ju ganska slitsamt. Men jag vet inte inte vad jag skulle läsa isåfallet...

Jag: Elev3, varför vill du bli fotograf?


Jag: Varför vill du bli polis?

Elev4: På en restaurang händer samma sak varje dag. I polisyrket vet man aldrig, det är spännande. Så... nu får vi besök.

Jag: Men vi är ändå klara, tack så mycket!

**Interview 2 (science students)**

Jag: Om ni tänker på ert drömjobb, eller ett jobb som ni skulle kunna tänka er att ha, vilka faktorer utmärker ett sådan bra jobb?

Elev1: Status

Jag: Status tycker du, vad tycker ni andra?

Elev2: Pengar

Jag: Är det samma sak status och pengar?

Alla elever: Nej!

Elev2: Pengar är mer för status.


Jag: Tycker ni andra samma?


Jag: Tycker ni andra att det är viktigt att ha ett intressant jobb?

Alla elever: Ja, självklart.

Jag: Vad är viktigast då, att ha ett intressant yrke eller ett med hög status?
Elev1: Det är nåt man får titta på själv för om man har en dröm om att bli typ...

Elev4: ...städare (hahah)

Elev1: Ja, men städare, det är ju inte så högt. Man kan alltid sikta lite högre.

Elev4: Det känns som om, det man prioriterar högre är ju att det ska vara intressant.

Elev3: Men om man har ett yrke med hög status, så är man inte nöjd med det, man är inte glad, hur länge kommer man orka fortsätta?

Elev5: Man ska göra det man gillar.

Elev2: Ja, annars kommer man ju inte orka ju.

Jag: Men är det det här ni tänker på nu när ni ska välja vidare karriär att det ska vara intressant och eventuellt lite bra pengar och lite sådär?

Elev1: Jag tänker bara på att ta studenten just nu. Så får vi se vad som händer.

Jag: Så det är det som har första prioritett just nu, du tänker inte vidare in i framtiden?


Jag: Det finns ju en massa andra yrken också som tur är...

Elev1: Ja, det är ju självklart men man går ju natur och...

Jag: Speciellt här i Tensta har jag upplevt att det är många som vill bli läkare bland natureleverna, av någon anledning.

Elev2: Men det känns ju som om har man gått tre år så vill man ju... jo jag ska bli läkare annars har jag slösat min tid (haha)

Elev1: Vi läser ju ändå natur forskning, det är ju typ det svåraste programmet. Och läsa det och sen jobba inom ekonomi det är ju bortkastat, för min del är det så. Så därför vill jag hellre bli läkare än...

Jag: Men som biomedicinsk analytiker då till exempel. Då jobbar man ju också på sjukhus och forskar kanske, hur skulle det vara?

Elev1: Nej jag vill inte bli forskare.


Jag: Då får ni jobba hårt, och ha lite tur också, för det är ju svårt att komma in på läkarlinjen. Men ok, vi går vidare. Om jag säger naturvetenskap och teknik, vilka yrken tänker ni på då?

Elev1: Allt inom medicin.

Elev4: Civilingenjör
Elev2: Forskare
Elev5: Biokemi
Jag: Vad tänkte du på?
Elev3: Jag tänkte också på forskare
Jag: Känner ni någon som jobbar inom de här yrkena?
Alla: Ja.
Jag: Är det närstående?
Elev2: Det är släkt.
Elev4: Ganska nära, min polares storebro har just gått ut KTH.
Elev2: Och min kompis storasyster blev precis klar med läkarlinjen.
Jag: Så ni har lite insyn i vad de olika yrkena innebär tycker ni?
Elev4: Ja... nej. Alltså
Elev5: Min mamma är forskare.
Jag: Din mamma är forskare? Inom vilket område?
Elev5: Stamceller.
Jag: Så det är biokemi alltså?
Elev5: Ja
Jag: Och de här faktorerna som vi pratade om i början, passar de in på dessa jobb, status, intressant...?
Elev4: Ja, civilingenjör gör ju det, läkare.
Övriga elever: ja...
Jag: Vad vill ni bli i framtiden? Vad har ni för drömmar?
Elev2: Läkare!
Jag: Du vill bli läkare, och du?
Jag: Men inom vilket eller vilka områden har du funderat då?

Elev3: Inom medicin.

Jag: Inom medicin nånting... Vad vill du då?

Elev5: Jag vill bli pilot. Men, jag blir nog läkare...

Jag: Men du blir nog läkare som dina föräldrar vill?

Elev4: Jag har ingen aning, när jag var yngre jag ville bli brandman. Fast min morsa sa nej, det är för farligt. Så jag vet inte, får se vad det kan bli. Men... kanske typ civilingenjör eller något sånt.

Elev1: Jag ville bli fotbolls spelare när jag var liten. Men det är ändrat. Jag kommer jobba med något inom medicin, det är jag helt säker på. Men inte forskare, jag vill inte bli forskare. Efter två veckor på KI så... (han skakar på huvudet)

Jag: Vad var det med det då som inte var bra?

Elev1: Nej, det var bara sitta framför en dator. Hon sa att det kan hända att hon sitter fjorton timmar om dagen på KI och bara analyserar. Och det är inte min grej.


Jag: Men varför tror du att det är så då, att alla vill ha samma typ av jobb? För det finns en sådan trend, frågar man gymnasieelever så är det några få jobb de nämner.

Elev2: Jag tror faktiskt att läkare är trendigt för statusen.

Jag: Att det är status?

Elev2: Ja, man vill säga att man är läkare.


Jag: Så brist på information tror ni? Tror ni det också?

Elev4: Nej alltså jag känner att... när man är liten man drömmer och så, och jag tror att man fortfarande drömmer... vi har inte fått känna på sanningen än (hahah).

Jag: Det hårdas livet?

Jag: Så man vet inte riktigt var man hamnar sedan ändå?

Elev4: Nej, precis.

Jag: Vad tror du?

Elev5: Brist på information.


Jag: De här yrkena som ni vill bli, känner ni någon som jobbar inom de områdena?

Alla elever: Ja.

Elev1: Jag har en nära vän som jag ser upp till.

Elev2: Ja, många i min släkt är läkare.

Jag: Så ni känner att ni har koll på de yrkena?

Alla elever: Ja.

Jag: Men då får jag tacka så mycket för att ni ställde upp!
Appendix 4 Cleaning and loading procedure

Cleaning and sample loading procedure for the aerosol collection test.

General procedures

Wear a coat. Use gloves whenever touching the sample holders or the tools. Touch the sample holders as little as possible, and use a tweezers. Clean all tools with ethanol before use. Use the special slippers in the cleanroom and use clean cover paper to work up on. If the sample holders have been used with glue before, make sure they are properly cleaned in an acetone bath overnight.

Estimated time of the procedure:

2.5 hours

Material needed at the laboratory workspace:

- 7 sample holders
- 100 ml beaker with de-ionized water

Material needed at the workspace in the cleanroom:

- Cupper grid
- Glas fiber filter paper
- 200 µl pipette with tips
- Tweezers
- Capillary
- 1 small box with cover for gel
- 1 bigger box with cover for sample holders
- Gel component A
- Gel component B
- Tool for 3 mm hole making
- Piece of wood
- Plastic cover
- Ethanol
- Dust-free napkins
- Paper cover the table

Gel preparation procedure

1. Turn on the oven, 100 °C
2. Put the sample holders in a clean beaker well covered with de-ionized water. Put the beaker in ultra-sonic bath for 30 minutes. Go on with step 3 while waiting.

![Sample holders in beaker and the beaker in ultrasonic bath](image1)

**Figur 1: Sample holders in beaker and the beaker in ultrasonic bath**

3. Go in to the clean room and prepare the gel on a glass by mixing 100 µl of component A and 100 µl of component B. Mix it careful with a clean pipette tip, and put it in a box with a top when finished.

![Preparations of the gel](image2)

**Figur 2: Preparations of the gel**
4. Be in the clean room when taking out the sample holders out from the beaker and put them on the table with clean paper beneath. Wipe them with some ethanol and clean napkin.

5. Let them dry for a minute and then apply with a capillary a droplet of gel on sample holders 2, 4, 5, 6, 7. See Figure 7. Put them directly in a sealed box when the gel is on.

![Figure 3: Put gel on sample holders](image)

6. Put the sample holders in the oven for 60 minutes in 100°C. Keep them in the box, but remove the cover in the oven.

![Figure 4: Sample holders in the oven](image)
7. Continue with filter and grid preparation while waiting.

**Filter and grid preparation**

1. Work in the clean room. Cover the smooth upper surface of the wooden piece with plastic and clean it with ethanol.

2. Put a big filter paper on the plastic top and make a 3 mm hole in it with the home made tool.

![Homemade tool for preparation of filters](image)

*Figur 5: Homemade tool for preparation of filters*

3. Take out the little filter circle from the tool with help of a tweezers. Put it in a clean small box and seal it.
4. Repeat step 2 and 3 above until you have enough 3 mm filter papers.
5. When the sample holders are finished in the oven, take the whole box in to the clean room and let them cool for a few minutes.
6. Put the 3 mm filter papers in the spot on sample holder no 1, 3, 6, 7 with a tweezers. See Figure 7.
7. Put 4 cupper grids in all sample holders; see Figure 7, with a tweezers. Make sure you have the correct side of it upwards, that is the less bright side where you can see the grids if you look closely.
8. Put all the sample holders back in the box seal it with a top and also plastic cover.
9. Store it in the cleanroom until time for test and analysis.
Figur 7: How to load the sample holders

Table 2: Name of the grids in the different positions and name of picture taken of them

<table>
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<th>No</th>
<th>No 1</th>
<th>No 2</th>
<th>No 3</th>
<th>No 4</th>
<th>No 6</th>
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<td></td>
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<tr>
<td>(upper)</td>
<td>B2</td>
<td>B3</td>
<td>A5</td>
<td>A4</td>
<td>A2</td>
<td>A3</td>
<td>B1</td>
</tr>
<tr>
<td>Grid 2</td>
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<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>(lower)</td>
<td>B5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Name of clean grid picture</td>
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<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
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<td>1</td>
</tr>
<tr>
<td></td>
<td>3 (lower)</td>
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