UNIVERSITETET I AGDER

The Relevance of Logarithms:

A study in two parts on the
relevance of logarithms for
students in upper secondary school

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This Master's Thesis is carried out as part of the education at the University of Agder and is therefore approved as a part of this education. However, this does not imply that the University answers for the methods that are used or the conclusions that are drawn.

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Preface

Writing this Master's Thesis has been a wonderful journey. Demanding and stressful at times, but mostly interesting, eye opening and… fun! I've spent a lot of time the past two years trying to figure out what I want to do research about, and I've been looking into several topics. In the autumn of 2016, I thought I had it all planned out: a local school was working with TRU-math (Schoenfeld, 2016). This looked like a promising topic and a potential supervisor was interested. Then suddenly I got an email from that school saying they were terminating the TRU-math project due to limited resources. And so, I was back to square one. This was when I learnt about professor Pauline Vos and her project on the relevance of mathematics, particularly of logarithms. The topic of this exciting project is to assist pupils in answering the question "why do I need to learn about this?" Who would have guessed that a 400 year old calculation device developed to help astronomers would be useful for sociologists and demographers?

The theory used in this research, Cultural-historical Activity Theory, has been a delight and a terror. It took me quite some time to get a good grip on it, and I keep learning more about it even now in the final weeks before the deadline. One thing I have learned during this process is to say: and now it is enough. Although there is still room for improvement, I need to go on. Everything could be made longer, deeper, better and more thorough, but I needed to keep it within the time limits.

I want to thank my supervisor, professor Pauline Vos, and my fellow student working on the same project for guidance, discussions and valuable input during the research and writing process. I also want to thank my fellow students at J2-002, my colleagues at the University of Agder and everyone here that have contributed to my research, my friend Håvard Dyrdal Fidjeland at the Norwegian School of Economics for his efforts and support, and the professors here that made their contributions, and Anders Støle Fidje for helping me making the video. I also want to thank the students that were interviewed and their teacher, for their time and contributions.

Last but not least, big, warm hugs to my beautiful, patient, funny, creative, playful two children who have been by my side and enthusiastic about playgrounds, various farm animals, tricycles and rattles, and my loving fiancée for her care, dinners and endless patience. This would not have been possible without you!

Anders Wiik

Kristiansand, May 2017

Sammendrag

Temaet for denne masteroppgaven er matematikkens relevans, spesifikt relevansen av logaritmer, for elever i videregående skole. Elever spør gjerne "hvorfor må jeg lære om dette?", og forskningen min tar sikte på å gi dem et svar på dette spørsmålet. Forskningen bestod av to mindre studier, Study 1 og Study 2. Study 1 handler om å finne ut av hvem, hvordan og hvorfor logaritmer brukes. I Study 2 blir denne informasjonen så kondensert ned til en kort instruksjonsfilm som tar sikt på å gi elever i målgruppen et svar på spørsmålet "hvorfor skal jeg lære om logaritmer?" For å teste kvaliteten på filmen, viser jeg denne til en gruppe elever i målgruppen og intervjuer dem. Disse intervjuene blir så analysert ved hjelp av kulturell-historisk virksomhetsteori for å finne ut av hvilke tanker de har om filmen og temaet.

Forskningsspørsmålene er 1) hvordan kan spørsmålet "hvorfor skal vi lære om logaritmer?" besvares? og 2) hvilke syn har elever i målgruppen på filmen min som er rettet mot å besvare spørsmålet "hvorfor skal jeg lære om dette?" Jeg har også en hypotese om at elever i målgruppen har lite kunnskaper om anvendelser av matematikk, og at de ønsker seg informasjon om dette.

Resultatene mine indikerer at 1) logaritmer har anvendelser i de fleste akademiske fagområder, og er potensielt relevant for mange elever som vurderer høyere utdanning og 2) at videoen min var generelt godt mottatt, men at det er a) vanskelig å balansere mengden detaljerte matematiske forklaringer mot enkelhet for å oppnå en tilgjengelig og lettforståelig presentasjon. Intervjuobjektene var delt på dette punktet. Også b) slike presentasjoner kan være kontraproduktive. Resultatene indikerer også at hypotesene er sanne. Enkelte av elevene indikerte at lærerne deres burde informere dem mer om anvendelser av de matematiske begrepene de lærer om. En større studie er nødvendig for å avgjøre hvilken presentasjonsform og innholdsbalanse som egner seg best for å presentere relevansen av matematiske emner for elever i videregående skole.

Stikkord: Matematikk, Utdanning, Relevans, Logaritmer, Videregående

Abstract

The topic of this master's thesis is the relevance of mathematics, specifically of logarithms, to students in upper secondary school. Students often ask "why do I need to learn about this". The aim of my research is to provide students with an answer to this question. The research consisted of two studies, Study 1 and Study 2. Study 1 aimed at figuring out by whom, how and why logarithms are used. Information about this was obtained by literature searches and expert appraisal. With Study 2, I condensed this information into a short educational video aiming at providing students in upper secondary school with an answer to the question "why do I need to learn about logarithms?" To test the quality of the video, it was shown to a group of eight students in the target group and they were interviewed. Using Cultural-historical Activity Theory (ChAT), these interviews were analysed to find out what views these students had on the video and on the relevance of logarithms.

The research questions were 1) how can the question "why do I need to learn about logarithms" be answered? and 2) what are students' views on my video aiming to answer the question "why do I need to learn about logarithms?" I also hypothesise that students in the target group know little about the applications of mathematics, and that this is information that they want.

My results indicate that 1) logarithms have applications in most scholarly fields and are potentially relevant to many students considering going into higher education (from sociology and demography, to medicine, engineering and natural sciences), 2) that my video was generally well received, but that a) it is difficult to balance the amount of detailed mathematical explanation with simplicity to achieve an accessible presentation. The target group was divided at this point. Also b) such presentations can be counterproductive. The results also indicate that the hypothesis is true. In fact, some students indicated that their teachers could inform them more about applications of mathematical concepts. However, a larger study is required to determine what presentation form and content balance is best suited for demonstrating the relevance of mathematical topics to students in upper secondary school.

Keywords: Mathematics, Education, Relevance, Logarithms, Upper-Secondary

Contents

1 Introduction

1.1 Motivation and Background for the Thesis

Many teachers of mathematics will meet the question *"why do we need to learn about this?"* This question from students asks about the relevance for them of what they are learning. This thesis focuses on relevance of mathematics, specifically of logarithms. In the following chapters, I want to assist students in giving an answer to this question, and investigate the student's reactions to this answer. This study is part of a larger study on relevance and on student's knowledge of the relevance of mathematics. We are two masters' students doing research on relevance of mathematics, focusing on different mathematical topics. Our supervisor is currently working on an article on relevance in mathematics education, and this article has provided some inspiration for this work.

Logarithms are useful for comparing quantities that differ by orders of magnitude. Thus, in visualizing data, particularly complex statistics, logarithms are valuable devices. In astronomy, chemistry, physics, medicine and many other hard sciences, logarithmic plots are abundant. However, there are also great examples of logarithmic plots in social sciences. The Swedish professor Hans Rösling, talking about the start of his career as a public speaker, says "There were two zeros difference in the number of [child]deaths: 30 in Sweden, 3000 in Mozambique." The author continues: "the 'difference of zeros' stayed with him and became the preoccupation that led eventually to what he does now" (Watts, 2009 p. 199). In other words, the quantitative difference that helped spark his academic career was a difference of orders of magnitude. In a later chapter, I will describe how Rösling uses logarithmic plots to visualize data.

Christof Weber (2016) argues, with a broad basis in the literature, that "logarithms have a reputation for being difficult and inaccessible" (p. 69). He points at the presentation of logarithms as the inverse of exponential functions as a probable cause of this difficulty. Perhaps another part of the reason for this difficulty is that the students do not perceive of logarithms as relevant to them. Geir Botten (2009), talking to a prominent (and unnamed) Norwegian politician about his occupation as mathematician, was met with the comment "…mathematics? I've often wondered how anyone can take interest in a topic so peculiar and distant from reality" (p. 21, translated from Norwegian). Distant from reality is perhaps the opposite of relevant; if this comment is symptomatic of the general population's attitude towards mathematics, then we as mathematics educators have a big job to do. Hans Werner Heymann (2003) similarly reports that even academics flaunt their ignorance of mathematics.

Figure 1: Do students actually get use for the mathematics they are learning? (Munroe, 2012)

1.2 Aim of the Study

The aim of this study is to assist students in mathematics classrooms to answer the question *"why do we need to learn about this?"* That involves finding out 1) an answer to this students' question that is convincing to myself and 2) simplify this answer into an answer that is accessible to students and 3) considering ways of presenting it materially (in a video), and finally putting the answer to the test: when I show the material to students, what responses do I get?

It is not possible for me to do this for the whole of mathematics, so this research was limited to logarithms. Logarithms are one of the more difficult topics within mathematics, so it is particularly pertinent to do research on logarithms.

1.3 Initial Hypotheses

I base my initial hypotheses on my own experiences as a teacher, pupil in primary education and student in secondary and tertiary education. It is that:

1) Students in upper secondary school have little knowledge of how the mathematics they learn is useful outside school. This can have many causes. One is that teachers often have a university background with subject-specific teacher education. Such an education gives little weight to how one can use the content, and the teacher educators likely knows little about these themselves..
2) Information on the relevance of mathematics is something many students want, and it can be motivating. The students have made a choice to go to a university-preparatory programme, and even selected the most demanding mathematics course available. Therefore I hypothesise that many of them have ambitions to study mathematics related topics at university of college level, and are interested in learning how the material they are currently learning about, is applied in other contexts.

I also assume that logarithms have more applications than I am aware of. I know of certain uses, like log plots, decibel and pH, but I would like to investigate more deeply and broadly *how* logarithms are used, for *what purpose* and *by whom*.

1.4 Research Questions and Operationalization

Building on my hypotheses, I formulate the two research questions that will guide the work in this research. They are

1) How can the question "why do I need to learn about logarithms" be answered?
2) What are students' views on my video aiming to answer the question "why do I need to learn about logarithms?"

The first question can be loosely translated to "what is the relevance of logarithms for students in upper secondary school". I will look at possible ways of demonstrating the relevance of logarithms and use secondary sources to investigate what the answer can contain. Based on these results and available information in the literature on perceptions of relevance, I will make a presentation of the material and finally investigate how a group of students in upper secondary school, familiar with logarithms, responds to this answer. I cannot look directly into the minds and thoughts of the students. To get an insight into their thoughts, the response was measured through statements made during an interview.

1.5 Structure of the study

In chapter 2, relevant literature is reviewed, and the theoretical framework is laid out in chapter 3.

In order to answer the two research questions, this study was split into two substudies, Study 1 and Study 2. Study 1 aimed at providing an answer to the first research question. The methods used in Study 1 are presented in chapter 4, and the results are presented in chapter 5. The discussion and conclusion of Study 1 is presented in chapter 6.

Study 2 aimed at answering the second research question. The methods and methodology for Study 2 are presented in chapter 7, the results thereof are presented in chapter 8 and the discussion and conclusion on the second research question is presented in chapter 9.

Chapter 10 sums up the results of the two studies, discusses the hypotheses and didactical implications, and possibilities for future work on the relevance of mathematics.

2 Literature Review on Relevance and Logarithms

2.1 Logarithms in the Curriculum

Logarithms are found in the mathematics curriculum for upper secondary school in many countries, including Norway and the Netherlands. However, the curriculum must be interpreted, and the exam tasks provided by the government are the predominant interpretation because these are what the student are ultimately assessed by. For these reasons, I will outline both the text in the curriculum and some examples of tasks from exams.

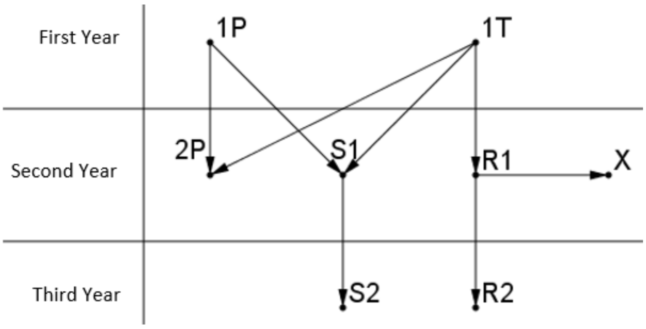


Figure 2: Structure of mathematics courses in Norwegian Upper secondary education. Mathematics is mandatory in the first and second year, but the content and scope differs. The arrows indicate what choices the students can make.

For students in upper secondary school in Norway, there are several mathematics courses to choose between, and it is possible to choose a path where you never encounter logarithms: the path P1-P2 (see figure 2). Logarithms appear explicitly in the curriculum for the courses 1T (T for Teoretisk, Theoretical), S1 and S2 (S for Samfunn, Society) and R1 (R for Realfag, loosely translatable to Science, Technology, Engineering and Mathematics, STEM), and it appears implicitly in R2. The students interviewed in this thesis are taking R1. Therefore, I will limit this section to 1T, the course they took last year, R1, the course that they are in now, and R2, the course many of them are preparing for.

Some students already take 1T in the last year of lower secondary school, and then they can take R1 in their first year in upper secondary school (Utdanningsdirektoratet, 2013b).

Admission to higher education is based on a score calculated from grades from upper secondary school as well as "age points", "language points" and so on. Getting a passing grade in R1 mathematics gives 0,5 "STEM points", giving an advantage in the admission process and an incentive for choosing R1 (Samordna Opptak, 2013).

2.1.1 Logarithms in 1T

In the first year in upper secondary school, students can choose 1T or 1P mathematics. The choice has implications for what courses can be chosen later, and certain university programmes, particularly within STEM topics, requires passing grades in R1 and R2. R1 and R2 can only be chosen after 1T, whereas choosing 1P is considered an "easier" option.

$$\lg\left(2x+\frac{3}{5}\right)=-1$$

Figure 3: Exam task from 1T, fall 2016.

The formal learning objectives related to logarithms are as follows:

> Reformulate expressions and solve equations, inequalities and systems of equations of the first and second order and simple equations with exponential and logarithmic functions, using algebra and digital aids (Utdanningsdirektoratet, 2013a).

The exam tasks show how the government interprets this (figure 3 and 4); the students are provided with a Briggsian logarithm containing a linear function or a conjugate, and this must be solved to obtain values for the unknown.

$$\lg(x^2 - 0{,}9) = -1$$

Figure 4: Exam task from 1T, spring 2015.

2.1.2 Logarithms in R1

R1 belongs to the second year of upper secondary education and builds on 1T mathematics. It thus presupposes that the student already has knowledge of logarithms from this course. R1 and R2 are generally considered the most advanced mathematics courses that are taught in Norwegian upper secondary school, and these prepares for further studies in Mathematics, Science, Engineering and Technology (STEM).

$$g(x) = x \ln x$$

Figure 5: Exam task from R1, fall 2016. The task is to differentiate

The formal learning objectives related to logarithms are as follows:

> Derive the basic arithmetical rules for logarithms, and use these and the power rules to simplify expressions and solve equations and inequalities
>
> Use formulae for the derivative of power, exponential and logarithmic functions, and differentiate composites, differences, products, quotients and combinations of these functions (Utdanningsdirektoratet, 2013c).

The tasks provided demonstrate a simple example of differentiating a product involving the natural logarithm (figure 5), and a relatively sophisticated example of a quadratic expression with a logarithmic variable (figure 6).

$$(\lg x)^2 + \lg x - 2 = 0$$

Figure 6: Exam task from R1, fall 2016.

2.1.3 Logarithms in R2

R2 belongs to the third and last year of upper secondary school, and the curriculum does not mention logarithms explicitly. The course builds on R1 and thus requires knowledge of logarithms. The logarithm tasks here are about integration, either integrating an expression involving logarithms (figure 7) or resulting in logarithms (figure 8).

$$\int x \cdot \ln x \, dx$$

Figure 7: Exam task from R2, spring 2015.

$$\int_1^e \frac{3}{x} dx \qquad \int \frac{2}{x^2 - 1} dx$$

Figure 8: Exam tasks from R2, spring 2016.

Overall, the curriculum emphasizes calculations and says little about contexts in which those calculations are useful.

2.1.4 Popular Tertiary Study Programmes

The most popular fields of study among Norwegian students in tertiary education are "health, social and sports", with a large proportion of females, "economy and administration", and STEM-fields, with a large proportion of males (Statistisk sentralbyrå, 2017). R1 and R2 are a requirement for many study programmes, including several engineering and science programmes[1]. Certain study programmes, particularly within economy, require or recommend either S1 and S2, or R1[2]. These statistics say nothing directly about the goals of the students in the target group, those takin R1 mathematics in Norwegian upper secondary school, but they can provide a hint at what study programmes are popular. Since the students in the target group are taking R1 mathematics and this course is a prerequisite or recommendation for certain study programmes, I assume that they are more likely to pursue tertiary studies within STEM and business and economy.

2.2 Perspectives on "Why Teach Mathematics"

I looked in the literature for ideas about "why teach mathematics?" Heyman (2003) wrote a book with this title and provides a list of "objectives of schools" (p. 7):

a) Preparation for later life
b) Promoting cultural competence
c) Developing an understanding of the world
d) Development of critical thinking
e) Developing a willingness to assume responsibility
f) Practice in communication and cooperation
g) Enhancing student's self esteem

These are, in his argument, "at the core of the concept of general education and personal development" (p. 7).

In an article with the same title, Ernest (2005) also provide seven categories for what it is "we want learners to gain from their school mathematics learning experience" (p. 28):

Table 1: Objectives of Mathematics Education

Objective	Content
1) Functional numeracy	Mathematical skills and numeracy sufficient for employment and functioning in society
2) Practical, work related knowledge	The capacity to solve problems in practical situations with mathematics
3) Advanced, specialist knowledge	Understanding and knowledge of advanced mathematics, in high school or university
4) Mathematical problem posing and solving	Deployment of mathematical knowledge in posing and solving mathematical problems
5) Mathematical confidence	Being confident in one's knowledge of mathematics, ability to use and apply it, and ability to acquire new knowledge and skills
6) Social empowerment through mathematics	Enabling learners to function as numerate, critical citizens, able to apply their knowledge in social and political contexts

[1] See e.g. Building Engineering, bachelor's at NTNU: https://www.ntnu.no/studier/fthingby
[2] See e.g. Economy and Administration, bachelor's at UiA: http://www.uia.no/studier/oekonomi-og-administrasjon

7) Appreciation of mathematics	A broad category involving, among other things, appreciating the importance of mathematics in various contexts and a sense of mathematics role in culture

Ernest's and Heyman's lists overlap, but Ernest's list differs from that of Heyman because Ernest makes a difference between practical and advanced knowledge. Functional numeracy may be an objective for all students in secondary education, but you can function perfectly well in society without knowledge of logarithms. If logarithms are relevant, it must be within the remaining categories. There are certainly work-related situations (2) where logarithms can be useful, more on that later. Many students taking R1 will go on to study programmes involving advanced mathematics (3), so further studies can also be a motive for learning about logarithms. Logarithms can be useful in mathematical problem solving and posing (4), particularly in situations involving exponential functions. However, this can be difficult to communicate. In development of mathematical confidence (5) and social empowerment (6), it is not obvious how a single concept can be directly applicable; these categories are asking for a larger picture. The final category (7) is interesting, and I believe elements from this category can capture the interest of many students. Appreciating the role and importance of logarithms in various academic and professional contexts can be a way of bridging the curriculum with activities outside of the school system.

These lists are formulated from the perspective of the educator, and may not comply with the answers expected by the learners. Wedege (2009) argues that any reason for teaching mathematics is value based and any reason the teacher can provide must be based on the content of the curriculum. She continues to argue that the problem of justifying teaching mathematical concepts, is divided into the global justification problem, "why do *we* have to learn about this" and the local justification problem, "why do I have to learn about this". The global justification problem asks for general reasons why the topic is taught, for example economic and political reasons, whereas the local justification problem is personal, "why should I have to engage in studying this particular aspect of mathematics" (p. 9). According to Skovsmose (2005), the motives a person has for learning are their foreground, that is, in the opportunities provided by their current social, political and cultural situation. That leads us to the next section, the perspective of the learner.

2.3 Perspectives on "Why Learn Mathematics" and Similar Studies

Examining pupils in an Ethiopian preparatory school, Gebremichael, Goodchild and Nygaard (2011) discovered eight categories of relevance grounded in their analysis. These are:

Table 2: Relevance of Mathematics

Mathematics is relevant because	Content
a) It is used in every day activity	Usefulness of mathematical concepts in activities like budgeting and various professions
b) It is used in other subjects	Mathematical concepts are applied in other school subjects like chemistry, physics and business

c)	It is useful in an unknown future	Mathematics is useful in ways that are unknown to the students; from the applications in every day activities, they infer that there are other applications in unknown activities
d)	Because it gives an identity	Performance in mathematics affects ambitions for future activities
e)	It empowers one to make informal decisions	Engaging with mathematics enhances your ability to analyse
f)	The student trust the curriculum	The students believes they should learn mathematics because their teacher tells them to
g)	It has exchange value	Success in mathematics is perceived as leading to a secure job
h)	It gives a fresh perspective of life	Adding spiritual meaning to mathematical concepts

Categories a), b), c), e) and f) are about the utility of mathematics, and d) and g) are about the road onwards in the educational system and how mathematics performance is useful for achieving academic and professional goals. The last form of relevance, spiritual meaning, is not related to usefulness in a practical, academic or work-related sense, but is about using mathematical concepts to mediate religious or spiritual thoughts. Comparing with Ernest's categories, a) and b) fits nicely into 1) and 2). c) does not have a clear-cut content and can conceivably fit into 1), 2), 3), 4) and 6). d) is about how performance in mathematics leads students to choose study programmes or professions with correspondingly high or low content of mathematics and is not covered by Ernest's list. e) complies with category 1), possibly also 2) and 3). f) is also about usefulness and can, like c), be grouped into 1), 2) or 3). g), like d), does not fit into any of Ernest's categories and h) fits within 7). Thus, juxtaposing the two lists, one reason for studying mathematics appears that is not on Ernest' list of reasons to teach mathematics: one can study mathematics because a good grade can give an advantage in further studies or jobs, in other words, mathematics can be relevant because it leads to a favourable study programme and/or job.

In a different article on the relevance of mathematics to chemistry students, Gebremichael (2014) found that first-year students tend to perceive that their mathematics courses are not relevant to their field of study, particularly during their first mathematics course. The students were not informed about how the mathematics they were learning was useful to their field of study. This perception changed during the second semester, when some calculus was applied in a chemistry course. The students in the study did not know about the uses of mathematics in chemistry beforehand. The author argues that "[t]he students and mathematics instructor needs to know the significance of the topics and the level of significance to the students' future use in the chemistry courses" (p. 158).

Jo Boaler has a chapter in her 2008 book "What's Math got to do with it?" called "What is Math? And why do we all Need it?" The latter question calls for some conception of relevance of mathematics, and her answer includes the aesthetical properties of the golden ratio, the mystical experience of realizing the importance of pi (as accounted for by a 10-year old), mathematical problem solving and the creative and exploratory nature of the subject.

In the Relevance of Science Education (ROSE) project, a large research endeavour initiated by Svein Sjøberg and Camilla Schreiner (2004), the researchers used quantitative methods to investigate what student's want to learn about in Science and Technology (S&T). The results from this study can say something about what pupils in this age group are interested in. Data were collected in about 40 countries in Europe, the Middle East, India, East Asia, Africa and Central America. The respondents were pupils at the age of 15 years. Their findings include:

a) Among pupils in the richest countries (including Norway), young people have more ambivalent attitudes than the adult population.
b) There is a growing gender difference with girls being more negative or ambivalent than boys, particularly in the richest countries
c) In more developed countries, the overall interest in S&T is lower.
d) Boys are more interested in science overall, and particularly the technical, mechanical, spectacular, violent and explosive .
e) Girls are more interested in health and medicine, beauty and the human body, ethics, aesthetics, wonder, speculation and the paranormal.
f) A peculiar oddity that breaks the pattern is "the possibility of life outside earth"; the most popular category for both girls and boys, with only small difference between higher and lower developed countries (Schreiner & Sjøberg, 2010).

Many of the applications of mathematics fall into S&T, and Schreiner and Sjøberg's (2010) findings therefore have implications for my research. It should be emphasised that the tendency for children from higher developed countries to be less interested in S&T is likely because children from lower developed countries regard education as a privilege, in contrast to richer children that can afford to be more selective in their interests (Schreiner et. al. 2010).

The ROSE project inspired the ROSME-project, the Relevance of School Mathematics Education (Julie & Mbekwa, 2005) which in turn provided the background for Suela Kacerja's (2012) doctoral dissertation. Julie and Mbekwa (2005) found that pupils in lower secondary in South Africa have a high preference for learning mathematics that will allow the pupils to attend tertiary schooling. Their respondents had a particularly high interest in health, possibly connected to the country's HIV and AIDS problems. Kacerja (2012) found that pupils in lower secondary school in Albania are more interested in mathematical activities that are useful in the professions they want to work with in the future, or future hobbies or interests.

Based on these findings, it would seem that there are two particularly pertinent ways of demonstrating the relevance of mathematics for students in upper secondary. The first way is to demonstrate the usefulness of mathematics in professions that individuals in the target group wants to work with (figure 9), here dubbed relevance as usefulness. The second form of relevance that I want to highlight is that something may be perceived as relevant because it can lead to a study programme that is a requirement or advantage for a profession that individuals in the target group wants to work with (figure 10), as Gebremichael et. al. (2011) found. The next challenge is to demonstrate this connection. The literature contains various means of demonstrating the relevance of mathematics to engineering students.

Mustoe and Croft (1999) suggest using case studies to show "the application of relatively simple mathematics to the forefront technologies" (Mustoe & Croft, 1999, p. 469) to students in upper secondary school in order to attract them into undergraduate engineering programmes. They highlight the difficulty of balancing the amount of mathematical explanation versus the realism of the case study. Too much emphasis on mathematical technique can detract attention from the application, and too simplistic mathematical models can mislead students into thinking that this is all the mathematics they will need in their studies is at a low level.

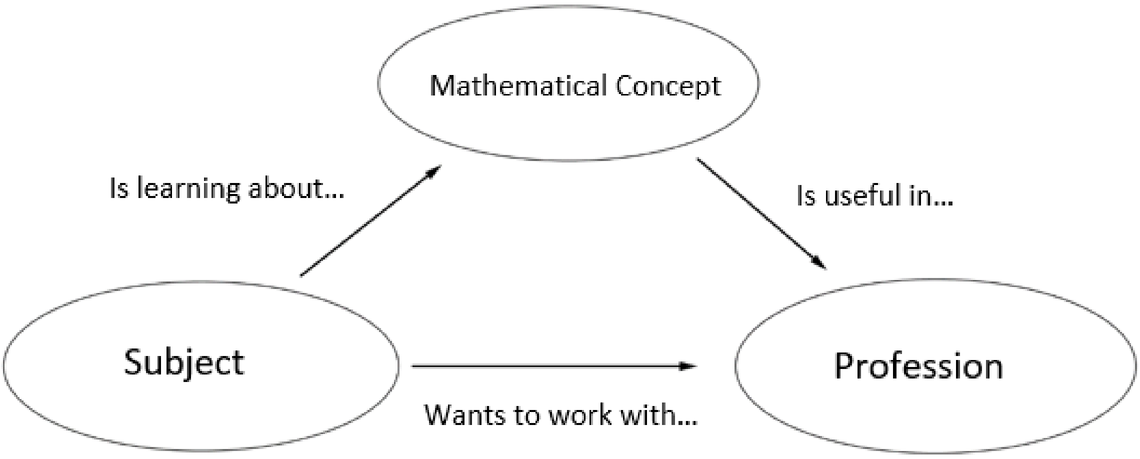


Figure 9: Relevance as usefulness in a future profession, as perceived by the learner (subject).

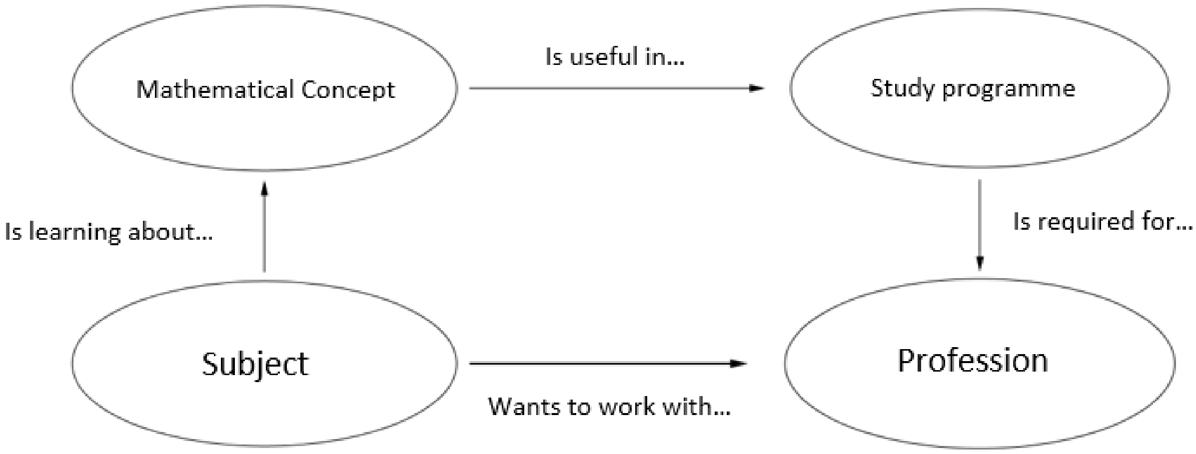


Figure 10: Relevance as requirement or advantage for future profession, as perceived by the learner (subject). Note that the mathematical concept may still be perceived as useful in the profession; relevance as usefulness and relevance as a requirement are not mutually exclusive.

Loch and Lamborn (2015) challenged two final-year engineering students and three final-year multimedia students to produce a resource that demonstrates the relevance of entry-level mathematics to first-year students. The background for the project is that students appeared to think that the mathematical concepts they were studying were not needed for their degree. They produced two videos showing how professional engineers apply concepts from first-year mathematics. The focus of the videos was to show "the role of mathematics […] not in a teaching way, but in […] a concept way" (p. 37). They were aware that they must try to find a balance between "too simple" and "too technical". They considered making many short segments and combine these into a longer video, where the short segments could be used in class, but were advised against this by the multimedia students because it would be too 'clunky' and lack 'overall flow'. The videos generated various feedback. One student, having previously failed in mathematics, experienced the video as a "scare campaign" (p. 11). They also found that the first-year students wanted proper explanations of the mathematics involved, and when the viewers did not understand every step in the videos, they found it overwhelming.

The literature also contains different approaches to demonstrating the relevance of mathematics to students in secondary and tertiary education. Suggested approaches include using realistic inquiry-based modelling problems (Wedelin & Adawi, 2014) and mixing authentic problems into the teaching as examples (Coupland, Gardner, & Carmody, 2008; Flegg, Mallet, & Lupton, 2012). Flegg et. al. (2012) found that engineering students seemed to agree that mathematics was relevant to their career. However, follow-up interviews revealed that the students were in fact much divided in this point, some seeing no relevance to their career at all. I will not go further into details on these studies since I am not using these approaches.

2.5 Relevance and Motivation

Several authors have emphasized the positive connection between relevance and motivation (see e.g. Frymier & Shulman, 1995; Weaver & Cottrell, 1988; Sass, 1989). A theoretical construct of particular interest here is Keller's ARCS model of motivation (Attention, Relevance, Confidence, Satisfaction) (Keller, 1983, 1987). In this model, relevance is one of the four building blocks of motivation and it is further divided into three subcategories: 1) goal orientation: relation between the instruction and the learners needs and goals; 2) motive matching: the link between the instruction and the learners interests and 3) familiarity: the connection between the instruction and the learner's experiences (Keller, 1987).

Another theoretical model that connects relevance to motivation is found in Geoffrey R. Barnes' (1999) PhD thesis. In his thesis, he explores the factors that affects children's choice of academic specialization. Among the factors in his model are "child's perception of task value" (p 22) including "intrinsic value" and "utility value" (p. 22). His model also includes future expectancies, which can be linked to career aspirations.

Kember, Ho and Hong (2008) interviewed 36 undergraduate students about what aspects of their teaching and learning environment that motivated or demotivated their study. Their findings indicated that establishing relevance was very important to the students, and that teaching abstract theory without context was demotivating. They proposed using a "curriculum map" showing how the material in basic courses is applied in more advanced courses. However, they also found that material demonstrating relevance can be a double-edged sword because the outcome were, in some cases, that the students could not see the relevance of the theoretical material. Because they expected that the material would be useful for them in preparing for their future career, this made some of the students demotivated. Thus, if material aimed at demonstrating the relevance of the curriculum fails to do so, then this can be demotivating to the student and work against its purpose.

2.6 Defining Relevance

In the literature on relevance in education, various definitions of the term have been proposed. John Keller formulated a definition in relation to his ARCS model of motivation. "*[R]elevance* refers to the learner's perception of personal need satisfaction in relation to the instruction, or whether a highly desired goal is perceived to be related to the instructional activity." (Keller, 1983, pp 395, emphasis in the original). This definition adds much weight to the instruction because it is about the emphasis of relevance in teaching.

Schreiner and Sjøberg (2004) uses relevance as an umbrella term for many factors that belong to the affective domain, seen from the student perspective. These include what the students like and dislike; their hopes, values and fears; and what kind of future they want to strive for. This definition gives much weight to the student perspective, and is very open as to what relevance actually is. It is difficult to distinguish between relevance and *interest* with this definition.

A third definition worth considering is given by Ernest (2004). In this work, relevance is a relation between three things: "a situation, activity or object R (that to which relevance is ascribed), second a person or group P (the ascribers of relevance to R), and third a goal G (embodying the values of P in this instance)" (p. 315). Using this approach, an object R is relevant when deemed so by one or more people P in achieving a goal G. This definition is interesting because it differs much from the previous definitions discussed. Here, there is no space for the perspective of the learner. Given the three elements, there is an objective relevance inherent in the situation.

The three definitions have varying degrees of openness and objectivity; Schreiner and Sjøberg's definition is very diffuse and is open for interpretation, and takes the perspective of the learner. Keller gives a more precise definition, and he also focuses on the learner's perspective. Finally, Ernest gives a definition that is objective and clear but leaves out the perspective of the learner. For the purposes of this thesis, I want a definition that focuses on the students' perception. I also need it to be independent of instructional activities, since the context is the life, hopes and aspirations of the students and not limited to classroom activities. Lastly, it need to have space for whatever meaning the students adds to the word so a strict, objective definition like that of Ernest is not desired. The definition I go with is something intermediate between Keller and Schreiner & Sjøberg: an activity is *Relevant* for a learner or learners if it perceived as helpful in achieving some goal. This definition will be further elaborated in section 3.3.

2.7 Historical Background

Logarithms are a relatively young mathematical invention, existing for some 400 years. In this section, I will give a short introduction to the history of logarithms.

To appreciate the importance of logarithms today, it is useful to have some idea of the historical background that led to their development. According to Katz (2004), the development of logarithms can be traced back to at least the sixteenth century. In this age, astronomers were making increasingly sophisticated computations with large numbers, and realized that the number of errors made could be greatly reduced by replacing multiplication and division by addition and subtraction. A different motivation was a table developed at the time, relating powers of 2 to their exponents and demonstrated that multiplication in one column correspond to addition in the other. With this motivation, John Napier (1550-1617) developed the first logarithm tables, and the first list of tables was published in 1614. In this work he used a different approach than the modern logarithm (the value of log(10 000 000) was zero). It took him 20 years to develop vast list of numbers. Later, he decided to take a different approach with $\log(1) = 0$ and $\log(10) = 1$. Then, the basic, familiar properties $\log(xy) = \log(x) + \log(y)$ and $\log\left(\frac{x}{y}\right) = \log(x) - \log(y)$ apply, and a close relation to the modern notion of standard form can be used; $\log(a \times 10^n) = \log(a) + n,\ 1 \leq a < 10$. Still following Katz, Jon Napier deceased before he could compile a new table based on these principles. Henry Briggs (1561-1630), with whom Napier worked closely on this matter, constructed the new table from scratch. This is the familiar Briggsian Logarithm base 10. He made calculations to 30 decimal places. Briggs table was completed by Adrian Vlacq in 1628, and was the foundation for nearly all logarithm tables into the twentieth century. Logarithms became a profound calculation tool for astronomers because it transforms multiplication into simpler addition, making computation easier and less prone to error. The Jesuit Alfonso Antonio de Sarasa (1618-1667) discovered the connection to the hyperbolic integral in 1649, and Nicolaus Mercator discovered the power series for the natural logarithm in 1668. Isaac Newton rediscovered this same power series and used it to calculate many values to over 50 decimal places. Using the laws of logarithms and clever arithmetic, he calculated the natural logarithms of many small positive integers. Leonard Euler (1707-1783) was the first to define the logarithm in terms of the exponential function. He used this to derive the basic properties, and he derived a power series applicable to multiple bases. The focus on power series is because it provided an accurate method for computing specific values (Katz, 2004). According to Weber (2016), logarithm tables were in common use until the onset of digital calculators in the late twentieth century. What is important to note is that in all cases, logarithms were a tool to ease calculations. Thus, in former times, learning logarithms was relevant for easing complex calculations. However, after the emergence of pocket calculators, logarithms no longer have this usefulness (Weber, 2016). Therefore, the question why students should learn logarithms in the era of pocket calculators is still pertinent.

2.8 Literature on Educational Videos

A *screencast* is a presentation of "digitally recorded playback of computer screen output which often contains audio narration" (Coined by Udell, 2005, cited by Sugar, Brown & Lutherbach, 2010, p. 1). In my research, I will create a screencast on the relevance of logarithms. Therefore, I also needed to study literature on designing educational screencasts.

Guo, Kim, and Rubin (2014) analysed how various "video production decisions affect student engagement in online educational videos" (p. 41). They used data from 6.9 million video watchings in a MOOC (Massive Open Online Course) and measured engagement by how much of the video the students saw, and whether they attempt to answer assessment questions after the video. Based on their main findings, they made a list of recommendations for video production. They are:

1) Invest heavily in pre-production lesson planning to segment videos into chunks shorter than 6 minutes.
2) Invest in post-production editing to display the instructors head at opportune times in the video.
3) Try filming in an informal setting; it might not be necessary to invest in big-budget studio productions.
4) Introduce motion and continuous visual flow into tutorials, along with extemporaneous speaking.
5) If instructors insist on recording classroom lectures, they should still plan with the MOOC-format in mind.
6) Coach instructors to bring out their enthusiasm and reassure that they do not need to purposely slow down.
7) For lectures, focus more on the first-watch experience; for tutorials, add support for rewatching and skimming (Guo, et. al., 2014).

Some of these points are more important than others for my work, particularly recommendations 1, 4, 6 and 7. The screencast that I made is a lecture, not a tutorial.

Another important source that is relevant in making screencasts is Mayer and Moreno (2003). In their article, they aim "to figure out how to use words and pictures to foster meaningful learning" (p. 43). A central issue here is cognitive overload: when "the learner's intended cognitive processing exceeds the learner's available cognitive capacity" (p. 43). Building on this, they describe five common overload scenarios, and ways to reduce cognitive overload in multimedia presentations for each of the five scenarios. In the following, I will describe each scenario and the authors' recommendations. Essential processing refers to the process of making sense of the presented material. Incidental processing is the processing of non-essential parts of the presented material, and representational holding is the maintenance of verbal or visual representations in working memory. The two channels are the visual channel and the auditory channel (see figure 11).

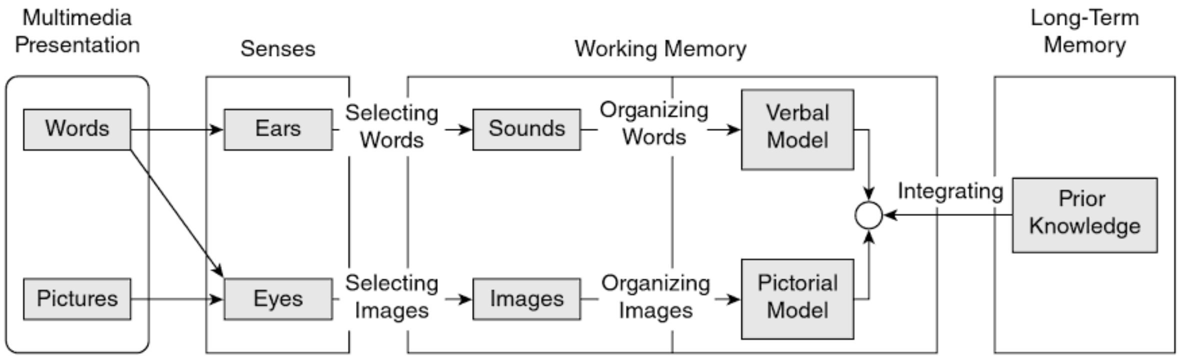


Figure 11: Cognitive Theory of Multimedia Learning. From Clark & Mayer, 2016, p. 35

Mayer and Moreno (2003) describes five forms of cognitive overload. They are summarized in the following text, and types 1, 2 and 4 are particularly pertinent to my research.

Type 1 overload: When essential processing overloads a channel. This can for example occur when you need to focus on a visual animation and a printed text simultaneously. Mayer and Moreno suggests solving this issue by off-loading, moving some processing from one channel to the other, like making the text auditory. This way, the text is processed through a different channel and the learners get a better understanding of the presentation.

Type 2 overload: Essential processing overloads both channels. This can occur in a multimedia resource with both visual animation and an audio narrative, and the topic is complex or presented too quickly. In this case, the learner will not be able to create an understanding of the subject matter. The authors propose two solutions to the problem. One is segmenting, dividing the topic into smaller chunks of appropriate size. This way, the learner can take breaks between the presentations. The second solution is to provide pretraining in names and characteristics of the topic. This is also a sequencing strategy, presenting the components before the whole.

Type 3 overload: Occurs when one or both channels are overloaded with essential or incidental processing. An example of this is if a learner looks up lightning in an multimedia encyclopaedia, and receives an animation with a narrative that explains how lightning is formed, requiring essential processing, and background music, requiring incidental processing. The authors propose two methods for solving this kind of issue. The first is called weeding, eliminating material that is interesting but extraneous, making the narrated animation as concise and coherent as possible. The other method is called signalling and reduces cognitive load by providing the learner with cues of how to select and organize the material, for example by emphasizing key words in speech, or using coloured arrows to focus attention of particular parts of the animation.

Type 4 overload: Can occur when essential and incidental processing overloads one or both channels. The difference from type three lies in the cause of the problem, which is a confusing presentation of essential material. This can for example happen when explanatory text is placed away from the graphics being explained. This can be avoided by aligning words and pictures, making it easier for the learner to connect the words with the animation. Another form of type four overload is when animation, narration and on-screen text is presented simultaneously, making it difficult for the learner to focus. Mayer and Moreno found that "[s]tudent understand a multimedia presentation better when words are presented as narration rather than narration and on-screen text" (p. 49), but when no animation is presented, "students learn better from a presentation of concurrent narration and on-screen text" (p. 49).

Type 5 overload: Occurs when essential processing and representational holding overloads one or both channels. This can for example occur in the scenario where the learner enters an entry on lightning in a multimedia encyclopaedia. The learner is first met by a short auditory narration explaining the formation of lightning, followed by an animation depicting the steps in this process. According to the cognitive theory of multimedia learning, this order of presentation can increase cognitive load because the learner must retain the verbal narrative in working memory while watching the animation. Mayer and Moreno propose solving this problem by synchronizing the auditory narrative and the animation (Mayer and Moreno, 2003).

3 Theoretical Framework

In this section, I will justify the selection of theoretical perspective (3.1), introduce this (3.2) and discuss how relevance fits into this model (3.3).

3.1 Theoretical Perspective

From the reviewed literature, some key properties of *relevance* emergeed. As discussed in the previous chapter, relevance has to do with an activity. When students ask "why are we doing this?", they were working on a task or they were listening to the explanation of a teacher. Also, relevance is subjective: an activity can be more relevant to the one person than to another. Also, relevance is connected with the goals of an activity, for example with a future profession of the students. Because of all of this, I needed a theory for investigating relevance which has something to say about the activities an individual engages in, and the goals of that activity, and the wider context of students (their peers, the school environment, their homes, etc.)

Engeström (2015) argues that cognitive theories are not sufficient to understand and explain learning activities. To say something about an individual and his/her relation to the world, it is necessary to say something about the history and culture the individual engages in. Based on the grand sociocultural theory of Vygotsky and his intellectual descendants, Cultural-historical Activity Theory (ChAT) has all of these important components (Engeström, 2015). ChAT will therefore serve as the theory and analysis tool in my research.

3.2 A Short Introduction to Cultural-historical Activity Theory

Engeström (2015) provides an outline of Cultural-historical Activity Theory (ChAT). ChAT originates in the work of Lev Vygotsky and his students in the 1920's and 30's. The second generation of activity theory, developed by Leont'ev, expanded upon Vygotsky's triangle of mediated action to include factors from the social milieu, specifically rules, community, division of labour and motive. Motive refers to the driving force of the activity system, whereas motivation refers to the driving force of the individual. The outcome are the intended and unintended consequences of the activities. Leont'ev defines activity in these terms:

> Activity is the nonadditive, molar unit of life … it is not a reaction or aggregate of reactions, but a system with its own structure, its own internal transformations, and its own development. (Leont'ev, 1979, p. 46, cited by Goodchild, 2001, p. 25)

Activities can be distinguished by their separate objects and it may not be obvious how an action contribute to the activity (Engeström, 2015). Engeström first employed the expanded triangle (figure 12) and coined the term "activity system", although the content stems from Leont'ev and Luria.

Engeström (2001) summarizes contemporary activity theory by five principles. Some of these, particularly number one and two, are particularly pertinent in my research.

The first principle is that the basic unit of analysis is a "collective, artefact-mediated and object-oriented activity system" (p. 136). Furthermore, goal-directed actions by individuals or groups, and automatic operations are subordinate units of analysis. These are only understandable when interpreted against entire activity systems.

The second principle is that activity systems are *multi-voiced*, a community of multiple "points of view, traditions and interests" (Engeström, 2001, p. 136).

The third principle is historicity. Activity systems are evolving and changing over time, and their problems and potentials can only be understood in context of their history.

The fourth principle is "the central role of *contradictions* as sources of changes and development" (p. 137, emphasis added).

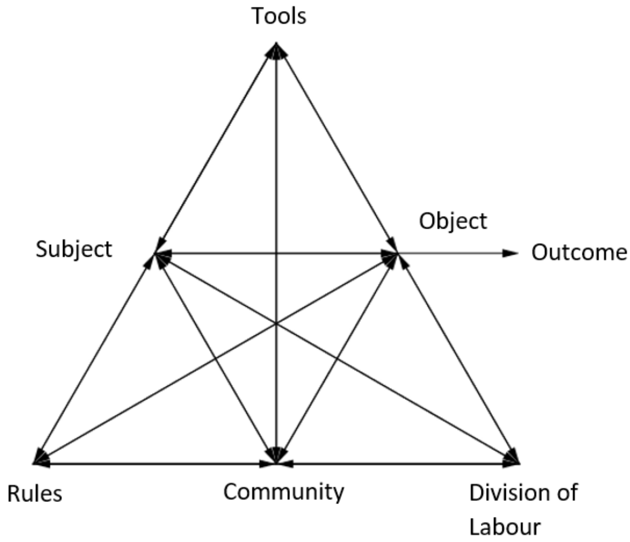


Figure 12: Second Generation Activity Theory (Adapted from Engeström, 2015)

Contradictions in activity theory are "historically accumulating structural tensions within and between activity systems" (p. 137).

The fifth principle is about what Engeström calls *expansive transformations*. As contradictions accumulate, some individuals in the system may begin to question the rules of the activity system. This can escalate to:

> [C]ollaborative envisioning and a deliberate collective change effort. An expansive transformation is achieved when the object and motive of the activity is reconceptualized (sic!) to embrace a radically wider horizon of possibilities (p. 137).

An activity system can be a smaller unit of a society, e.g. a hospital or a family (Engeström, 2001) or a band of hunters (Leont'ev, 1981). Furthermore, a person may engage in different activity systems at the same time (Engeström, 2015). To illustrate, consider the example of a mathematics classroom activity system. There is a blackboard and chalk, textbooks, note books, pencils, a language and so on (tools), there is a didactical contract and a set of social norms (rules), a group of students and a teacher (community), the teacher is orchestrating, lecturing, and so on, and the students are working on exercises (division of labour). Each subject (i.e. the students and the teacher) are working towards some immediate goal, like completing the tasks or understanding some mathematical concept (object), and they are engaging in the activity system in order to achieve some end, for example getting the grades required for admission to a particular university (motive). The same student also engages in an activity system where the motive is to be an integrated part of society with a job and a family. Here, the person is surrounded by peers and family (community), is a student and helps with housework (division of labour) and is regulated by social norms and laws (rules). There is a variety of mediating artefacts (tools).

3.3 Relevance in ChAT

Engeström (2015) highlights a contradiction within schools. The role of school for the student is twofold: In the activity system where 'school going' is the central activity, the object of the activity is to become an "instrument of success" and an "instrument of concept mastery" (p. 82). As the term "instrument" suggests, these are tools for the student in the activity of integration into society. That is, school has the double object of a) preparing the students for successful participation in society and b) teaching the students to master a certain content. However, in what Engeström calls "learning activity", learning is "an unintentional and inseparable aspect of the basic work activity" (p. 75). In school, the content is cut out of its context, and Engeström uses the term "text" for content detached from its context. In his wording, the text becomes a closed world. This may be particularly true of mathematics in secondary education. Thus, school has an inherent problem in that the content, the texts, are objectives and not tools, in contrast with learning activities where the text is a tool and learning is a by-product.

Building on the definitions of relevance discussed in section 2.6, *relevance* can be explored in terms of activity systems. It is meaningless to talk about an objective relevance; it is a judgement, perceived by the subject (Keller, 1983). Furthermore, relevance is connected with the objective or motive of an activity (Ernest, 2004, 2005; Keller, 1983). In short, relevance refers here to a person (subject) or persons (community) perception that an activity (learning about logarithms) is, or will be useful in achieving goals. In the context of what Engeström writes, in order for some school content to be relevant, it must move from the role of object to the role of tool.

Relevance is different from other affective perceptions, such as for example 'interesting'. Relevance is connected with goals (object and motive), whereas the property of being interesting is about capturing someone's attention (Interesting, n.d.). For example, a piece of music may hold my attention for some time and thus be interesting. At the same time, I do not perceive of music as helpful to me in achieving any of my goals, so it is not relevant to me.

4 Study 1: Method

The goal of Study 1 is to answer the first research question, "how can the question 'why do I need to learn about logarithms?' be answered". The methods used to gather data ought to be expedient in answering this research question. In this method chapter, I will give a detailed description of the methods for gathering data (4.1), and give some reflections on the validity and trustworthiness of these methods (4.2), and ethical considerations (4.3).

4.1 Data Collection

To get an answer that justifies the teaching of logarithms to students in upper secondary, it is necessary to get a picture of the uses of logarithms. Because two particularly important sources of relevance of mathematics for students in secondary education is the usefulness of mathematics in tertiary studies (Ernest, 2005; Gebremichael et. al., 2011; Julie & Mbekwa, 2005; Kacerja, 2012) and future work situations (Gebremichael et. al., 2011; Kacerja, 2008; Julie & Mbekwa, 2005), the answers ought to be connected with tertiary study programmes that the students are likely to attend, and jobs they are likely to engage with. The students in the target group are already attending a programme in upper secondary that is leading to further education in university or college, so uses in relevant study programmes are of particular interest. Academic sources are also relatively accessible to me through the internet and books in the university library. I have not been in contact with professionals outside academia in this research because of time constraints. I assume that the material presented in undergraduate textbooks is potentially relevant to professionals working in these fields outside academia.

This part of the research was done mostly in February and March 2017, with primary and secondary sources (Jacobsen, 2005). The primary data were obtained by asking experts (staff members of a university and a college) in various fields if, how and when logarithms are relevant to them and their work. I selected them by using the staff list of the department of mathematics and natural sciences of a certain university in South Norway, and a college of economy in West Norway. There were 12 experts addressed, of whom 8 replied. I asked face-to-face, and by email. I formulated a standard email (see appendix 12.4), and this was tailored to each recipient. In some cases, I also sent an email with follow-up questions, but these were never answered.

I also searched in secondary sources. Extensive keyword searches in online journals (e.g. International Journal of Renewable Energy; Sociology) and research databases (e.g. Google Scholar; Oria) with keywords like "log", "logarithm", "logarithms", "log-plot", "log-log plot", "semi-log plot" were used alone and in combination with other keywords like "medicine", "robotics", "physics", "demography", "engineering" etc. I wanted recent examples, so newer publications were preferred, although some older, "milestone" results are considered too.

The keyword searches provided many examples of applications, but it proved difficult to get an overview of the fields. Another challenge was that many authors only write "log" when they use logarithms (e.g. Arlegi et. al., 2017). However, the use of "log" as a search term was very difficult, because it has multiple meanings (this was particularly challenging in the International Journal of Renewable Energy, because log, i.e. timber, is a form of biomass that is currently extensively researched). Some search engines also returned hits for words containing "log", like "socio*log*y" and "psycho*log*y".

Introductory textbooks proved to be a good way to get an overview. I compiled introductory textbooks on biology, biochemistry, econometrics, economy, physics, mathematics for economy and business, mathematics for engineers, pure mathematics (calculus, algebra, linear algebra, number theory, statistics, etc.) and more, and looked up "logarithm" and related keywords in the indexes. I also used other books, including the meta-study "The Princeton Companion to Mathematics" (Gowers, Barrow-Green, & Leader, 2008) and "A New Kind of Science" (Wolfram, 2002).

A few examples were found from my own memory and from conversations with fellow students.

The results of this work are presented in section 5.1.

4.2 Validity and Trustworthiness

A weakness with my approach is that all sources were academic. I did not get in touch with engineers or other people in other mathematics-related professions outside academia to find out if, how and when logarithms are relevant to their professional activities. The main reason for omitting this was time constraints. Furthermore, considering that the target group is students undertaking relatively advanced mathematics and preparing for further studies in university or college, academic uses of logarithms may be a primary source of relevance to them, perhaps more so than non-academic uses. Thus, the bias towards academia is not necessarily negative. I also assume that the examples provided in textbooks are potentially relevant to non-academic professions in related fields.

Another bias in the search process was the use of concepts recalled from memory, because my own interests influence this. However, there are several things that I have in common with the target group, including that I am relatively young and that I, too, chose R1 mathematics when I was in upper secondary school. Thus, I may have a relatively good insight into their world, so this may also be an advantage.

Parts of the research was systematic: for the major fields, I used keyword searches in large databases; keyword searches in major journals; and index searches in textbooks. These three approaches gives insight into recent, peer-reviewed developments (database and journal searches), and milestone achievements in the field (textbooks). Thus, I argue, this approach gives a good picture of the status of uses of logarithms in the field in focus. In other fields, including sociology and psychology, the search was limited to keyword searches in databases and journals.

In the case of mathematics, I used a meta-study of the major developments within the major branches in mathematics the past few centuries (Gowers et. al., 2008), combined with the perspectives of active mathematicians and currently used text books on various major topics (calculus, linear algebra, etc.) This approach gives insight into milestone works and the topics that students in the target group are likely to encounter when they enter tertiary education. I also hoped to get insight into recent developments within mathematics that utilize logarithms, but no such applications were uncovered.

The primary aim of this study was to demonstrate the existence of applications in fields that are potentially relevant to students in the target group. It may be that the applications themselves are relevant to students in the target group, but in many cases, the mere existence of applications will suffice.

4.3 Ethical Considerations

When asking for help and input in gathering data about applications of logarithms by e-mail, I was careful in clarifying the purpose of the request. The respondents are people working or studying full time, and were in no way forced to reply. I also made it clear how I would use their response (see standard email, appendix 12.4). In those cases where a person did not reply, I did not send any further requests. Of course, all contributors and respondents were thanked for their time and contribution and their names were anonymised.

5 Study 1: Results and Analysis

In the following sections, I will present the results from Study 1, aiming to provide an answer to the question "why do I need to learn about logarithms?". The answer consist of various applications of logarithms and is presented by the disciplines in which it is applied, starting with mathematics (5.1) and statistics (5.2) and then the applications I have found in other disciplines (5.3-5.11).

When I go back to my experiences in school and university courses, I recall certain applications of logarithms. These include various scales for measuring intensity, like the Richter magnitude scale for the strength of earthquakes and the Decibel scale for measuring sound intensity. Other applications that come to mind include measuring acidity, the pH-scale. In the following sections, I will describe some of the various applications that surfaced during Study 1. I will limit the results to a few examples from each field hoping that I can use these to give a broad answer to the question "why do I need to learn about logarithms?" This way, I hope that I can reach a large section of the target group in making logarithms relevant.

5.1 Relevance of Logarithms for Mathematicians

I have asked several mathematicians at UiA, through email and direct conversation, for applications and the relevance of logarithms. The responses included:

1) The natural logarithm is the inverse function to the exponential function, making it useful in many situations that involves analysing exponential functions (Mathematician1, UiA; Mathematician2, UiA).
2) It is the solution to $\int \frac{dx}{x} = \int x^{-1} dx$, thus completing monomial integration (Mathematician1, UiA)
3) It is connected to the Euler number, e (Mathematician1, UiA)
4) It is one of the transcendental functions (Mathematician1, UiA)
5) It reduces multiplication to addition (Mathematician1, UiA)
6) It is connected with "Euler's Identity", the equation $e^{\pi i} + 1 = 0$ (Mathematician1, UiA)
7) Logarithm of a matrix (Mathematician3, UiA). On this topic, I did a quick search in Google Scholar and it revealed that logarithms of matrices are much researched within mathematics (see e.g. Culver, 1966 and Cheng, Higham, Kenney & Laub, 2001). The search did not reveal any applications outside of pure mathematics.

When I looked up "logarithm" in the index of The Princeton Guide to Mathematics (Gowers et al., 2008), I found several applications of logarithms within mathematics. They are used to establish the isomorphism $\langle \mathbb{R}^+, \cdot \rangle \simeq \langle \mathbb{R}, + \rangle$, thereby establishing that the cardinality of positive real numbers equals the cardinality of real numbers, and the natural logarithm appears in the important integral $\int dx/x = \ln(x) + C$ (Gowers, 2008a). Following Gowers (2008b), one famous problem in mathematics is to estimate $\pi(n)$, the number of primes less than or equal to n. It was conjectured by Legendre that the density of primes, i.e. the probability that an integer close to n is prime, is roughly $1/\ln(n)$. This suggests that $\pi(n) \approx \int_0^n dx/\ln(x) = li(n)$. The Prime Number Theorem builds on this idea and states that $\lim_{n\to\infty} \frac{li(n)}{\pi(n)} = 1$, that is, as n approaches infinity, $li(n)$ approaches $\pi(n)$. Jaques Hadamard and Charles Jean de la Vallée-Poussin proved this independently in 1896 (Gowers, 2008b).

Thus, logarithms have many ways of being relevant to mathematicians. It appears that logarithms are helpful to work with other concepts (integrals, exponentials, e, π, matrices), thus logarithms are a tool in the activity system of mathematical activities. Not one of the mathematicians, and not one book, said that the logarithm is important by its own right, that is: as an object in the activity system of doing mathematics.

5.2 Relevance of Logarithms for Statisticians

Browsing the tables of content of various books on statistics (Devore & Berk, 2012; Larsen & Marx, 2012) and econometrics (Greene, 2012; Wooldridge, 2010), I found long lists of topics like "log-normal distribution", "log-linear model", "log-likelihood function" and "logit-function". The technical details of these applications are quite advanced but the important thing to notice for the purposes of this study is that they exist. These applications of logarithms are used to re-scale or transform other functions.

In statistics, a class of functions in statistics of particular interest is power laws. These appear in many contexts (psychology, physics, economy, etc.) and they enable one to work with a linear model rather than with a power model. A linear model is relatively easier to analyse than a power model. The transformation of the power model $f(x) = ax^{-k}$ will yield $\ln(f(x)) = \ln(a) - k\ln(x)$, i.e. a linear model with respect to $\ln(x)$ (Statistician, UiA).

Benford's law is a mathematical device that makes it possible to uncover irregularities in statistical material. In short, the law states that in listings, tables of statistics, etc., written in base 10, the probability that the leading digit is D is given by $P(D) = \log\left(1 + \frac{1}{D}\right) for\ D = 1, \dots, 9$ (Weisstein, n.d.)

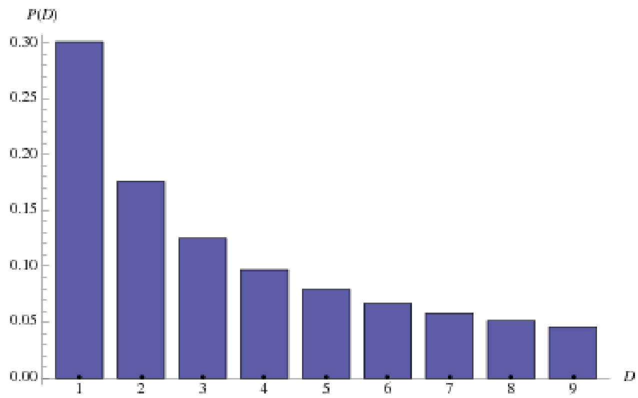


Figure 13: Benford's Law Probability Distribution. Weisstein (n.d.)

This law (figure 13) applies to a wide variety of datasets, and significant deviations from the distribution can be used to reveal misconduct. It has also be shown to be applicable to certain probability distributions (Leemis, Schmeiser, & Evans, 2000). In the following, I will give a short review of some applications of Benford's law in various disciplines.

The law is used to detect possible misrepresentations in financial datasets (Grabiński & Paszek, 2013; Johnson & Weggenmann, 2013; Tušan, 2016). T. P. Hill (1998) discusses a possible use of the law to make computer algorithms more efficient and provides examples of fraud detection by Benford's law. A method for detecting problems in survey data using Benford's Law has been developed and it has been used to investigate the quality of statistics about crop production in various countries; several abnormalities were found (Judge & Schechter, 2009). It has been shown that prices in certain eBay auctions obey the law, implying that it is unlikely that these prices are influenced by bidder collusion and interference by the seller (Giles, 2007). The law coincides with data from photon fluxes of bright objects, earthquake depths, global infectious disease cases, and a vast number of other statistics in science, and has been used to detect earthquakes (Sambridge, Tkalčić, & Jackson, 2010). The same authors propose that it can be used for checking the realism of computer simulations of complex physical phenomena like climate or ocean dynamics.

Thus, logarithms have several applications in statistics. (Semi-) logarithmic plots are used to visualise statistical data, and this will be covered in the following sections.

5.3 Relevance of Logarithms in Medicine

My search provided several examples of uses of log-plots in medicine. One example that has already been used in research on the didactics of logarithms is a graph of perinatal mortality, that is: the risk of death immediately before or after birth (figure 14). Here, the y-axis, perinatal mortality, is logarithmic and is plotted against birthweight (linear) (Vos & Espedal, 2016). In this statistical diagram, the mortality is given as a rate for which only one significant figure matters. Thus, the mortality is above five out of ten (500 per thousand) when the birthweight is below 1500 gram, or below five per thousand when the birthweight is between 3000 and 4500 gram.

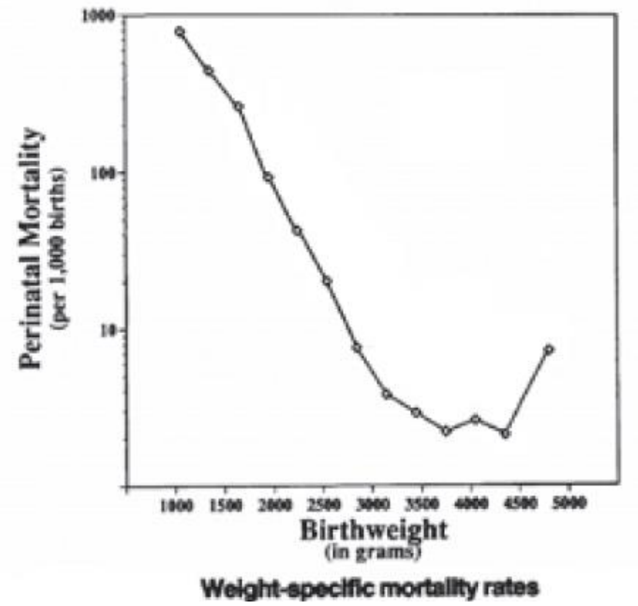


Figure 14: (Vos & Espedal, 2016, p. 30) This is a graph of mortality immediately before and after birth, plotted against birthweight.

By using a logarithmic scale, the authors can simultaneously show "few" and "many".

In an online guide on ways to visualize medical data and exemplifying the use of logarithmic plots, Centres for Disease Control and Prevention (2012) displays a graph of five of the fifteen leading causes of death in in United States (Figure 15). This graph is also semi-logarithmic with logarithmic y-axis and linear x-axis. The y-axis is labelled at powers of ten and four intermediate values, giving readers a good chance to see how other numbers are distributed in-between.

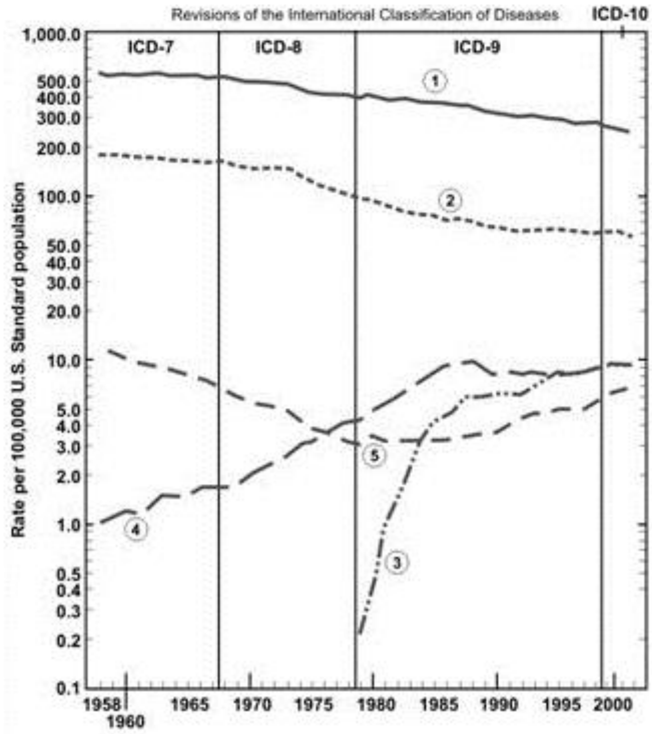


Figure 15: Disease occurrence per 100 000 U.S. population. 1: Disease of Heart. 2: Cerebrovascular Disease. 3: Alzheimer disease. 4: Septicaemia. 5: Assault. From Centres for Disease Control and Prevention, 2012

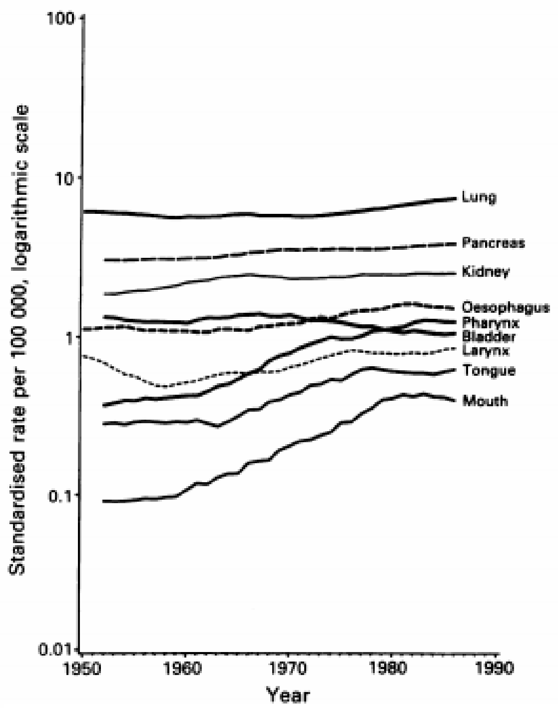


Figure 16: Mortality Trends for tobacco and/or alcohol-related cancer sites, French females, age 35-64. From Hill, Benhamou & Doyon (1991) p. 589

Another example is a graph of mortality trends for tobacco and alcohol related cancer sites among French females, age 35-64 (figure 16) (C. Hill, Benhamou, & Doyon, 1991). This article contains more logarithmic plots. I chose this one because it is relatively tidy with few overlaps There are examples of studies of protein functions that are using log plots and logarithms in analysing data (Kumar, 2016; Kämpf, Klameth, & Vogel, 2012) and DNA mobility (Stellwagen, 2017).

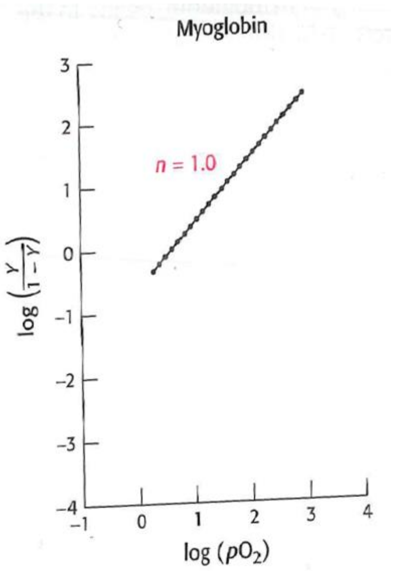
Thus, in the activity system of medicine, logarithms are used as a tool to show data simultaneously, which are “few” and “many”, and other uses.

5.4 Relevance of Logarithms in Chemistry and Biology

According to a Biotechnician at UiA, logarithms are indispensable in chemistry because acidity, pH, is by definition the negative Briggsian logarithm of the concentration of hydronium. The acidity pH is so essential in chemistry that you need to master logarithms to complete an education in chemistry, biochemistry and pharmacy (Biotechnician, UiA). In modelling the binding process of myoglobin and haemoglobin, logarithms are applied in the Hill equation (Equation 1) and the related Hill-plot (figure 17), which are used to obtain the Hill coefficient that "measures the cooperativity of oxygen binding" (Berg, Tymoczko & Stryer, 2007, p. 200).

$$log\left(\frac{Y}{1-Y}\right) = n\ log(pO_2) - n\ log(P_{50})$$

Equation 1: The Hill Equation. Y is the fractional saturation, P50 is the partial pressure of oxygen at which it is half saturated and pO2 is the partial pressure of oxygen. n is the Hill coefficient. From Berg, Tymoczko & Stryer, 2007, p. 200



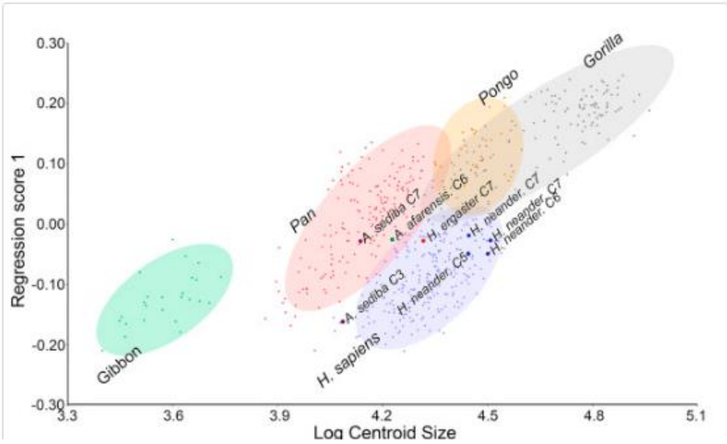


Figure 18: Evolution of the Hominin Spine. From Arlegi et. al. (2017).

Figure 17: Hill-plot of Myoglobin. From Berg, Tymoczko & Stryer, 2007 p. 200)

Another application of logarithms in biological sciences is found in allometry, the study of the proportion between different body parts (Allometry, 2014). Logarithms are applied in the study of bone lengths in dinosaur fossils (Franz et al., 2009; Grillo & Delcourt, 2017) and proboscis length in bees (Cariveau et al., 2016). A recent study on the evolution of the spine in hominins uses logarithmic plots to visualize data (figure 18; Arlegi et. al., 2017).

Thus, in the activity systems of biology and chemistry logarithms are an essential tool to model biological and chemical phenomena.

5.5 Relevance of Logarithms in Psychology and Pedagogy

Siegler and Booth (2004) demonstrated that children tend to estimate the magnitude of a number logarithmically. Children in kindergarten, first grade and second grade (6-8 years old) were asked to estimate the position of various numbers between 0 and 100 on a number line with only 0 and 100 plotted. The patterns is clear: in kindergarten, the children evaluate the numbers logarithmically, and gradually make a transition to a more linear evaluation in second grade. The accuracy of the estimate was also strongly correlated with their SAT-9 score, suggesting that children initially evaluate numbers logarithmically and gradually transition to a linear evaluation as their mathematical skills develop (Siegler & Booth, 2004). A similar tendency to overestimate the magnitude of small numbers and underestimating larger numbers has been found among indigenous Amazonian cultures without formal education (Spelke, Dehaene, Izard, & Pica, 2008).

The Hick-Hyman law (also known as Hick's law) is about reaction time and states that the time it takes to make a decision increases logarithmically when the number of choices increases (Hick, 1952; Hyman, 1953). There are, however, exceptions to the law (Longstreth, El-Zahhar, & Alcorn, 1985). Another logarithmic model of human behaviour from the fifties is Fitts' law, describing the time it takes to reach a target as a function of distance and target width (Fitts, 1954).

A more general statement about the logarithmic nature of perception is the Weber-Fechner law. It is "an approximately accurate generalization in psychology: the intensity of a sensation is proportional to the logarithm of the intensity of the stimulus causing it" (Weber-Fechner law, n.d.).

Thus, in the activity system of psychology and pedagogy logarithms are, amongst others, a tool to describe patterns in human behaviour.

5.6 Relevance of Logarithms in Sociology

I made a quick search for "logarithm" in the journal "Sociology" and found several results. Maas and van Leeuwen (2016) use logarithms, logistic regression and a log-linear model in analysing trends in social mobility, that is, the degree to which men can escape their social class of birth, among men in European countries during the industrialization.

Smångs (2016) presents a theoretical framework for analysing how violence between social groups contributes to activate and maintain group categories, boundaries and identities, also accounting for the role or organizations in the process. He goes on to apply this framework to lynching in the southern states of USA to demonstrate the advantages of his framework. His method involves the natural logarithm of several variables, including "the natural logarithm of absolute black population size" (p. 1351) and "the natural logarithm of time elapsed from the beginning of the study period" (p. 1352).

Thus, in the activity system of sociology logarithms are, amongst others, a tool to model social phenomena.

5.7 Relevance of Logarithms in Demography

The Swedish professor of international health Hans Rösling, has led the development of the website and foundation 'Gapminder'[3]. The aim of this foundation is to fight "devastating misconceptions about global development" (Gapminder, n.d.-a). The work published on this website includes animated graphs with display options for the reader, like the graph in the screenshot in figure 20 (Gapminder, n.d.-b). This graph is semi-logarithmic, the y-axis is linear, showing life expectancy, and the x-axis is logarithmic, showing price- and inflation adjusted gross domestic product per capita. The bubbles represent countries, and the size represents population. The colour indicates region. There is also a time axis: by clicking play, the graph runs through the data from year 1800 up to today. The watcher has the option to highlight one or more countries and add tracing, making it easier to follow trajectories and make comparisons.

be denoted by L_x, and λ be the characteristic of a logarithm, or such that $\lambda(L_x)$ may denote the logarithm of that number, that if $\lambda(L_a) - \lambda(L_{a+r}) = m$, $\lambda(L_{a+r}) - \lambda(L_{a+2r}) = mp$,

Figure 19: Excerpt from Gompertz, 1825, p. 519

The Gompertz-Makeham law of mortality (Gompertz, 1825; Makeham, 1860) is a model describing mortality rates. It states that the human death rate is the sum of an age-independent component (e.g. availability of penicillin) and an age-dependent component, which increases exponentially with age. To visualise this law, logarithms are used, and Gompertz used logarithms in deriving this law (figure 19).

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[3] More information on Gapminder can be found here: http://www.gapminder.org/about-gapminder/

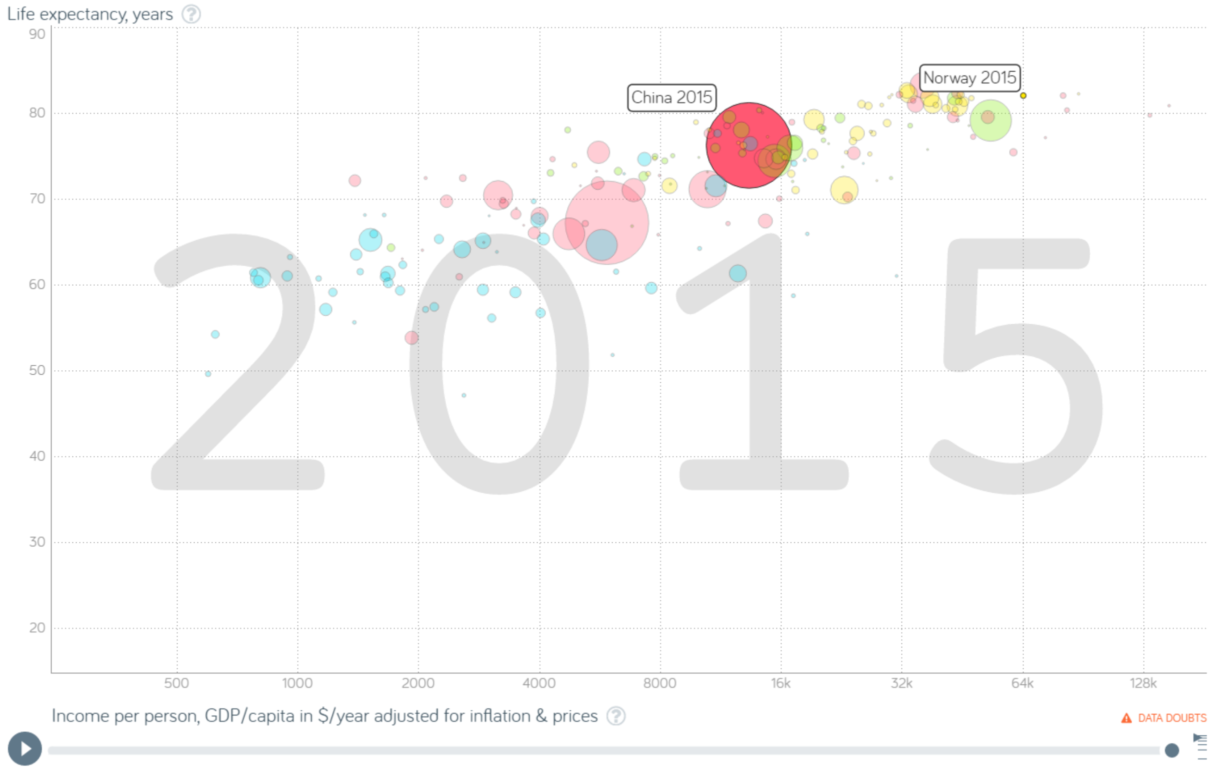


Figure 20: Wealth and Health of nations. Notice that the x-axis is logarithmic. The bubble represent countries, and the size of the bubbles represent population numbers. Here, Norway and China is highlighted. Colours indicate region. The graphs is animated with a time-axis, enabling the watcher to trace the development of health and economy from 1800 through 2015. It is also possible to add tracing, making it easier to follow trajectories and make comparisons.

5.8 Relevance of Logarithms in Economy

For students of economy, such as those at Norges Handelshøyskole (NHH), logarithms are most relevant for those specialising in finance and economic analysis, and logarithms are used in programming (Master's Student, NHH).

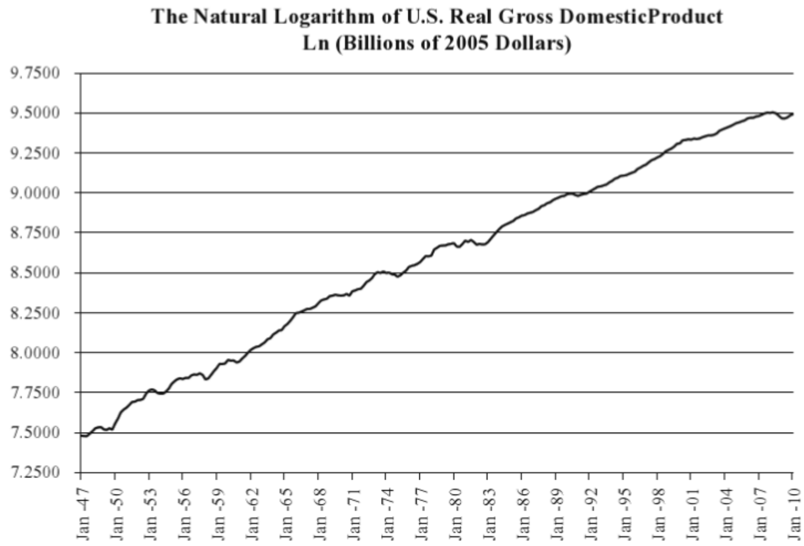


Figure 21: From Salemi (2013) p. 29: Applications of Mathematics in Economics. This graph is part of a task to evaluate the development of gross domestic product mathematically.

Textbooks in econometry go into topics like log-logistic hazard functions, logit models, log-odds transformation, lognormal hurdle, log-likelihood function, log-quadratic cost functions and loglinear (regressions) models (Greene, 2012; Wooldrige, 2010). Many textbooks on mathematics for economy and business presents logarithms in the context of analysing exponential models and calculating compound interest (Jacques, 2006; Pemberton & Rau, 2013; Sommervoll, 2016).

The graph in figure 21 shows the natural logarithm of the real U.S. GDP from a book on applied mathematics in economics (Salemi, 2013). The graph is valuable because it is from an important and popular field of study, it is authentic insofar that the data are real, and it visualises an important property of the logarithmic function, the transformation of an exponential function to a linear one.

In his milestone work "Why stock markets crash", Sornette (2009) claims that market crashes are 'log-periodic', and illustrates this with figure 22, a semi-log-plot of the Nikkei index, with a dashed periodic regression line:

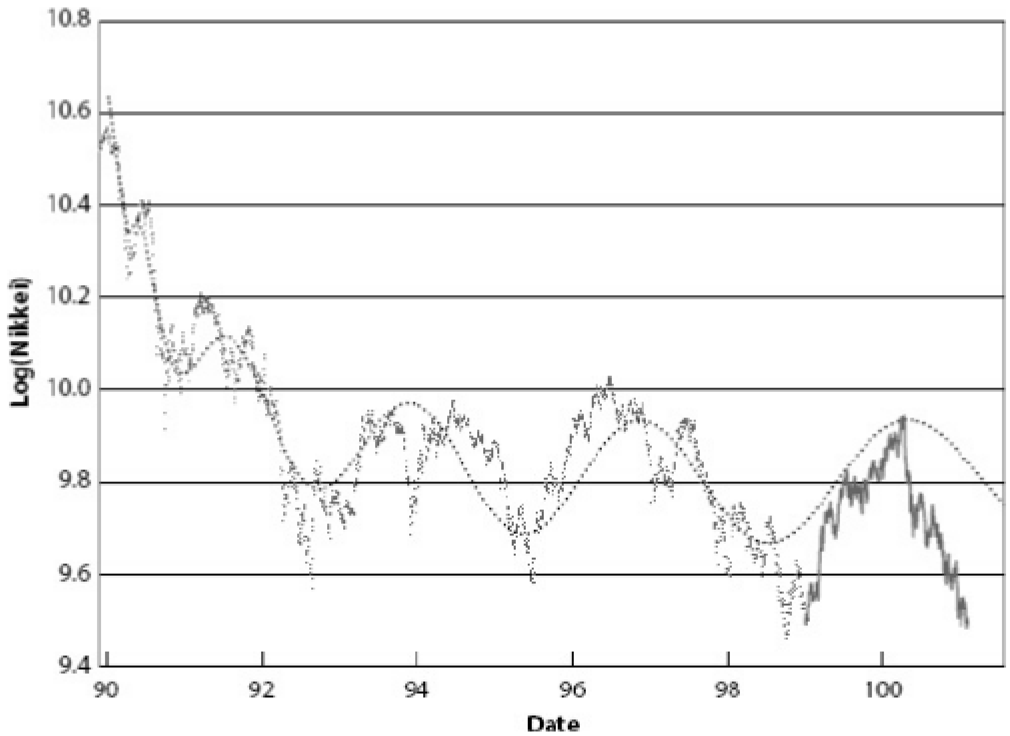


Figure 22: Semi- logarithmic plot of the Nikkei index. The dashed line is a log-periodic approximation. From Sornette (2009), p 259.

5.9 Relevance of Logarithms in Physics

The natural logarithm is applied in thermodynamics: calculating pressure gradients with increasing height; the Boltzmann distribution; calculating work in a heat machine; the partition function and much more (Grøn, 2015).

Astrophysics deals with vast frames of time and space, and this is reflected in the use of logarithmic axes in graphs. Examples include the Hertzsprung-Russell diagrams, graphs of the observable universe, nucleosynthesis in the early universe, timeline of light in the universe, radiation temperature after the big bang and more (Freedman, Geller, & Kaufmann, 2011)

5.10 Relevance of Logarithms in Renewable Energy and Engineering

Recent examples from the journal "Renewable energy" include several articles that somehow use logarithms. An article on numerical modelling of pressure changes over time (McLean & Zarrouk, 2015) shows several logarithmic plots and figures; an article on energy saving in solar powered refrigerators (Meng, Zheng, Wang, & Li, 2013) uses logarithms in data analysis as well as semi-logarithmic plots. Two articles on biodiesel production (Li, Zou, Zhou, & Lin, 2017; Ma, Wang, Sun, Wu, & Gao, 2017) use semi-logarithmic plots, and the latter also uses logarithms in exponential regression.

Recent examples of applications of logarithms from "The International Journal of Robotics Research" include a fascinating piece of research on bipedal robotic architectures that includes a semi-logarithmic plot on the number of steps various bipedal robots managed to take on various surfaces (Laumond, Benallegue, Carpentier, & Berthoz, 2016). There are also several articles on the related issue of kinodynamic planning, i.e. "to synthesize a robot motion subject to simultaneous kinematic constraints" (Donald, Xavier, Canny & Reif, 1993, p 1049), for example Otte and Frazzoli (2015) and Pham, Caron, Lertkultanon and Nakamura (2016). These articles are discussing computational complexity (see section 5.1.11) of various algorithms on robot motion.

Thus, logarithms are relevant in the activity systems of researchers of renewable energy and engineering, and logarithms are here used to present and analyse data.

5.11 Relevance of Logarithms in Discrete Mathematics, Information Technology and Cryptography

Cryptography is a science closely related to number theory and information technology and it is immensely important for its applications in communication security. Barker, Chen, Roginsky & Smid (2013) write about discrete logarithms in cryptography. The mathematical details are too advanced for the purposes of this thesis since the discrete logarithm is a concept from the theory of elliptic curves, but it is interesting to notice its existence.

Certain computer algorithms have a logarithmic time complexity, that is, the time it takes to execute a computation increases logarithmically as the problem increases in size (Rosen, 2007). This includes the binary search algorithm, a computer algorithm for searching through an ordered dataset (Rosen, 2007).

The Shannon-Hartley theorem provides a maximum bound of the rate of information transmission over a communication channel with noise, stated as $I \leq \frac{1}{2} log\left(1 + \frac{\tau^2}{\sigma^2}\right)$ (Price & Woodruff, 2012). The details of the mathematical statements, other that the fact that it contains the Briggsian logarithm is not of interest for this thesis. However, the examples show that logarithms are also used in the activity systems of Discrete Mathematics, Information Technology and Cryptography.

6 Study 1: Discussion and Conclusion

Implicit in the question "why do I need to learn about logarithms", there are three subquestions: 1) by *whom* are logarithms used, 2) *how* are they using logarithms, and 3) *for what purpose,* that is, *why* are they using logarithms.

The first question is answered implicitly by the categorization of the results: mathematicians, statisticians, engineers, economists, sociologists, psychologists, physicists, medical doctors, biologists and chemists use logarithms, and the lists could probably be made much longer.

I can also answer the second question, at least in part, through the results. Logarithms are for the most part used for *transformation* of data; transforming a difficult or messy dataset into something that is more transparent (a model) and easier to communicate (a visualisation). The various applications encountered can, roughly, be grouped into four categories by how logarithms are applied:

Table 3: Applications of Logarithms

Application	Explanation
1. Logarithmic scales	Logarithmic scales are the instances where a magnitude is interpreted logarithmically, that is, a logarithm is used to transform the data. This includes measurements for acidity (pH), decibel (dB) and earthquakes (Richter's scale), but also perception models: as the Weber-Fechner law states, "the intensity of a sensation is roughly proportional to the logarithm of the stimulus causing it" (Weber-Fechner, n.d.), implying that a multitude of sensations follow a roughly logarithmic scale.
2. Logarithmic and semi-logarithmic plots	This is the largest category, and includes all graphical representations of graphs and/or datasets in two dimensions, possibly more, where one or more of the axes have logarithmic scales. Examples includes Hill-plots, and the other graphs from the literature that were highlighted in the preceding section.
3. Logarithms as calculation devices	Logarithms are a valuable tool for calculations, particularly in statistics but also situations where it is necessary to analyse exponential functions. The Hill Equation and Benford's Law falls within this category, as do exponential regression, the logit-function and much more.

The third part of the question, *why* are these people using logarithms, can also be answered by the data. The mathematicians have the goal of doing mathematics for themselves and their own community, and sometimes logarithms are the appropriate tool for working with other mathematical concepts. Also, the physicists, engineers, economists, sociologists and so on all use logarithms as a tool; it can be a communication tool, for making a dataset more easy to grasp, or it can be an analysis tool, for calculating compound interest, a statistical parameter, and so on.

There are at least two different reasons for making logarithmic and semi-logarithmic plots. One reason is to make it easier to visually compare large and small magnitudes in a plot, as in the dynamic plots from Gapminder and the highlighted graphs from medicine. The second reason is to make an exponential or approximately exponential function come out as a linear function, making it easier to analyse. This is the case with the Hill-plot and the graph from Salemi where he has presented a graph of the US gross domestic product, an approximately exponential function, on a logarithmic plot, for educational purposes. Sornette's log-periodic stock-index analysis falls within the same category, although it has an additional periodic component.

An interesting finding here is that logarithms are used *exclusively* as a tool (figure 23). Among all the sources that I explored, logarithms were never an object or motive in itself. As Engeström reflects, the things that are tools outside of school are objects for the students inside school. Building on this, in the school activity system, logarithms are a learning objective and a tool for solving equations, but in the object activity, the activity of the student aimed at becoming an integrated member of society, logarithms can be a tool for achieving certain grades or filling requirements for studies and jobs. Finally, logarithms can be a tool in the activity system of students in tertiary education, and in the activity of people in work situation.

I also content that some of the results can be relevant in other contexts than tertiary education and work. Knowledge of perinatal mortality can be relevant to a student if the s/he is considering having a child in the future, and knowledge of demography can be relevant to student goals in other school subjects. However, extending the argument into claiming that *logarithms* are relevant because of this is a long stretch.

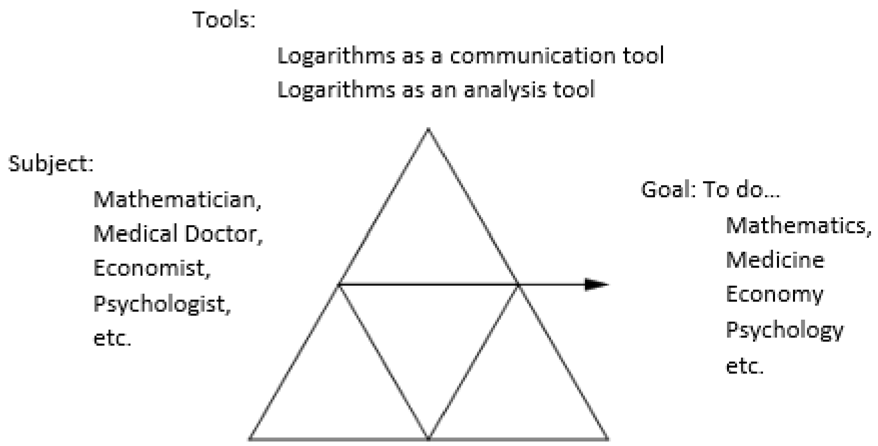


Figure 23: The Relevance of Logarithms

The first research question was "how can the question 'why do I need to learn about logarithms' be answered?", and the answer can be summarized this way:

a) Students need to learn about logarithms because it is used as a tool in fields like mathematics, medicine, economy, physics, engineering, psychology, sociology and many more fields, and some of these fields may be of interest to the students. Students may encounter logarithms in studying these fields, and in working within these fields.
b) The people using logarithms are using them in many ways and for many purposes. Shortly summarized, logarithms are used as a communication tool in presentation of data in the form of logarithmic scales and plots, and logarithms are used as an analysis tool in many settings; as a tool for analysing and building statistical models, which is important in all fields that employ statistical methods; in population modelling; economic analysis; and much more.

c) Many people will never use logarithms actively in work related situations, and I did not find instances in which logarithms are directly relevant to day-to-day activities. However, for students in upper secondary school, we cannot predict whether this applies to them or not. This also answers the general justification problem "why do we have to learn about this".

This concludes the first research question and thus Study 1.

7 Study 2: Methods and Methodology

With the foundation of an answer to the first research question, it is possible to start on Study 2, which is aimed at answering the second research question: "what are students' views on my video aiming to answer the question 'why do I need to learn about logarithms?'"

The methods for this process started by making a video, which I consider as a research instrument. This process is described in section 7.1. The next part of Study 2 is to test this instrument on a group of students in the target group, and interviewing them (7.2). First I have a short discussion about the research paradigm this part of the research is situated within and a discussion of issues related to epistemology, ontology and methodology (7.2.1). Then I present the method for conducting the interviews (7.2.2), research context (7.2.3), ethical considerations (7.2.4), the use of audio (7.2.5), strategy for data analysis and transcriptions (7.2.6) and validity and trustworthiness (7.2.7).

7.1 Making the Video

The first step was to make the video. It was a screencast, and it aimed at providing the students in the target group with an answer to the question "why do I need to learn about logarithms?" The answer ought to reach out to as many of the students in the target group as possible. Therefore, the presentation ought to follow the following criteria:

Table 4: Objectives of the Presentation

Objective	Explanation
1) Easy to understand	The examples ought be easy to understand, so that no students lose interest or are deterred because it is difficult
2) Obvious connection to logarithms	The role of logarithms in the examples must be apparent to the viewer
3) Relevant and broad	The examples ought to be *potentially* relevant to the target group. Also, the presentation ought to present a broad range of examples, in terms of field of application and method of application, so that it has the potential to be relevant to a large group of students
4) Engaging production	The screencast ought to follow the reviewed advice on reducing cognitive load (Mayer & Moreno, 2003) and engaging production (Guo et al., 2014)

Objectives 1), 2) and 3) can easily come into conflict, so compromises between the amount of mathematic technique and mathematical simplicity must be made on the way (Mustoe & Croft, 1999; Loch & Lamborn, 2015). Objective 2) is also a didactical challenge: how can I make the connection apparent between the examples and logarithms? That is, how can I best explain the way logarithms are used without high demand on knowledge of logarithms? This also requires that I select the examples in a smart way and present them in a smart order. With objective 4), I intend the selected examples to be something that is likely to be perceived as relevant by the students in the target group. As I did not know beforehand the students individual objectives and motives, I had to make educated guesses based on available information: the results from the ROSE-project (Schreiner & Sjøberg, 2010); admission statistics (Statistisk sentralbyrå, 2017) and my own gut-feeling. The admission statistics have some weaknesses. They are statistics for all students currently in tertiary education, and says nothing of the choices made by students in the target group. Furthermore, the statistic shows

what study programmes the students are taking, not what they applied for. Because the students in the interview have actively chosen R1 mathematics, it is probable that these students are more likely to pursue study programmes that require or recommend R1. For example STEM and business and economy. Because of the great diversity of perspectives (the multivoicedness) in the classroom, it was unlikely that some examples would be engaging to all students. Therefore, I opted to present a variation of applications (objective 3).

Some topics proved to be hard to present in an accessible way. For example, the first editions of the screencast also had a part presenting Benford's Law. This part was cut out because it was too time consuming to present it in an understandable manner.

I considered different media for presenting the relevance of logarithms to students. I could give an oral presentation (lecture method), I could show them a poster, or I wish I could have the possibility to show them a BBC-like documentary. Out of all the possibilities, I chose to make a short screencast for several reasons. An online video is easily distributed, making it readily available to a broad audience. A video can also appeal to multiple senses through multiple modalities; there is the possibility to combine spoken and written text, dynamic and static pictures and graphs, and I can use zooming and the cursor to highlight parts of the graphs and animations. Another important reason is that a screencast can be repeated, ensuring that all the students get the same input during the interviews.

The video that I made is a screencast (Sugar, Brown, & Luterbach, 2010), which is made by recording the computer screen with a voiceover. I made it by talking through a power point presentation, interrupted by a dynamic graph with commentary. Although it is recommended that my face be shown at opportune moments as I speak (Guo et al., 2014), I decided not to do this as it would require advanced equipment, a lot of extra time and a lot of time and help from colleagues. In the following text, "screencast" is used to talk about my screencast, and "video" is used when I am discussing videos in general. The screencast recording was made through a process of trial and error. The first editions were far too long, exceeding ten minutes. With new editions, some content was cut out; the audio narrative was improved based on re-listening and feedback from colleagues, my supervisor and fellow students; and details were added to some of the graphs to make them easier to understand and avoid cognitive overload. All in all, I made 27 versions before I judged the screencast fit to show to students. Table 5 presents the content of each part of the screencast, time span of the different parts, the object with presenting this content in that order, and short descriptions of the presentation. Figures 23 through 28 are excerpts from the screencast, and are connected with table 5. Appendix 12.5 contains screenshots from all parts of the screencast.

In accordance with the advice from Guo et. al. (2003), the length of the screencast is below 6 minutes, and any small, unnecessary pauses, superfluous words and mispronunciations were cut out in the editing process. I have described the choices I made to avoid cognitive overload in table 5. Mayer and Moreno (2003) argue that type 2 overload can occur when the topic is complex and presented too quickly, and that this problem can be remedied with pretraining in characteristics of the topic. Because they recently learned about logarithms, particularly the Briggsian logarithm and the natural logarithms, I assume that they have already received pretraining in these concepts.

The screencast is named "Hvorfor skal vi lære om logaritmer?", Norwegian for "Why do we need to learn about logarithms?". I have uploaded it to YouTube, and a link is provided at the end of this chapter.

Table 5: The Content used in the screencast, in chronological order

Content, timespan	Explanation and objective
Historical context, 0:00-0:25	I start by giving a short explanation to the cultural and historical role of logarithms. This is connected with learning mathematics as a part of our culture and history (Ernest, 2005). The spoken text is also shown as written text because students learn better this way, when there is no animation (Mayer & Moreno, 2003).
Gross domestic product, per capita, 0:25-0:47	A list of GDP, authentic numbers from the international monetary fund, with a semi-random selection of numbers from the richest and the poorest countries, as well as intermediate numbers, is presented along with the statement that logarithms are useful for comparing numbers of different orders of magnitude. This dataset is chosen because a) gross domestic product is more interesting to compare logarithmically than linearly, and b) the number line is much easier to interpret when it is presented logarithmically. Norway (Norge) and the US (USA) are included to make the content more interesting for the students. The most important parts of the spoken text is also shown written, because students learn better this way when no animation is presented (Mayer & Moreno, 2003).
Gross domestic product, per capita, on number lines, 0:47-1:31	The same numbers are presented visually on two number lines. The first line is linear, meaning that the poorer countries are clustered in the lower end of the scale although these numbers differ by a large factor. Then the same numbers are presented visually on a logarithmic axis where they are evenly spread out, contrasted with the linear number line. The object with this presentation is to exemplify to the students how a logarithmic axis can be useful and why they are used. See figures 24a and b. The spoken text is not shown in written text to avoid type 4 overload (Mayer & Moreno, 2003), and the parts of the number lines that I talk about are highlighted by zooming and using the cursor, which are methods for signalling to the student where to focus attention, to avoid type 3 overload (Mayer Moreno, 2003)
Two semi-logarithmic plots from medicine, 1:31-2:45	Two semi-logarithmic plots are presented, along with a statement that logarithmic representations of numbers are used within nearly all scholarly fields. The first graph presents leading causes of death in the US for a period (figure 24), and the second graph presents infant mortality as a function of birthweight, see figure 25. These examples are chosen because they are a) connected with health, a favourite topic for girls (Schreiner & Sjøberg, 2010), b) they are connected with death, an important topic, and child birth, something that may become relevant to many of the students within a decade or two. Also c) these graphs are significantly clearer by the use of logarithmic axes, making the usefulness of logarithms clear. The screencast is zoomed in on the graphs to hide the title of the slide, weeding out superfluous information, and I use red lines to highlight the parts of the second graphs that I am talking about, signalling to the students where to focus (figure 26; Mayer & Moreno, 2003).
Two semi-logarithmic plots from economy,	Two more semi-logarithmic plots are presented, this time from economy. The first graph is an example of a graph in which an approximately exponential function becomes linear when presented logarithmically. The second graph shows the logarithm of a stock market index, see figure 27.

2:45-3:06	The objective of including these graphs is to demonstrate that (semi-) logarithmic plots are used within economy, not to give a deeper understanding of the analysis potential with these graphs.
Summary of the fields where logarithms are applied, 3:06-3:24	The next slide contains a list of scholarly fields in which logarithms are applied, illustrated with pictures. The list starts with fields that are traditionally seen as incorporating much mathematics and many students will study in the future, like renewable energy research and engineering. These are then contrasted with fields that may not be associated with mathematics in the same way, like sociology and psychology. The list ends with "… and much, much more", implying correctly that this is in no way an exhaustive list. Then the screen is filled with various, complicated formulae involving logarithms. Figure 28 shows how the screen looks like in the end of this part of the screencast. Most of the formulae are from textbooks on econometrics, but formulae from chemistry, demography and pure mathematics are also included. The intention is only to demonstrate the broadness of applications, so this is not mentioned. The object of this part of the presentation is to demonstrate that logarithms are applied in many fields, including fields not typically associated with mathematics, and that the use is not limited to plots and animations.
Gapminder-animation, 3:24-4:23	In the next part, I talk though an animation from the Gapminder foundation, demonstrating the development in health and wealth of the world's countries from the year 1800 to 2015. The animation contains hints of major events in recent history: During the second world war, there is a sudden drop in life expectancy, and the explosive economic development in all the world's countries in the last fifty years appears clearly. The object of this part of the presentation is to clearly demonstrate the usefulness of logarithmic plots as a communication tool, linking it with historical events that the students hopefully can relate to. I use the cursor to signal the students what parts of the graph I am talking about (figure 29).
Cardinality of real numbers, 4:23-4:40	In the final part, I present one of the mathematical results that can be obtained with logarithms, the surprising and strange result that the cardinality of the real numbers equals the cardinality of the positive real numbers. This result is a consequence of the fact that logarithms can be used to establish an isomorphism between the real numbers with multiplication, and the positive real numbers with addition, but this theorem is not mentioned in the video. The object of including this result is to explain to the viewers that a) logarithms is relevant within mathematics, b) logarithms have applications other than (semi-) logarithmic plots, and c) demonstrate that logarithms can lead to surprising, unexpected results. There is no animation, so the spoken text is summarized with written text, following the advice from Guo etl al. (2003)

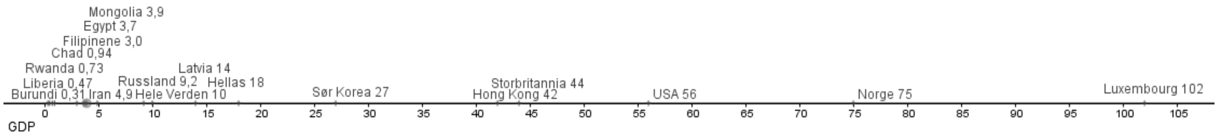


Figure 24a: Gross Domestic Product, linear representation. The numbers are obtained from the International Monetary Fund

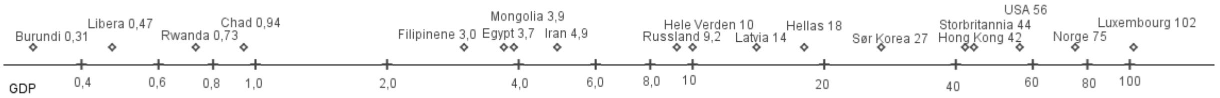


Figure 24b: The same numbers, presented logarithmically

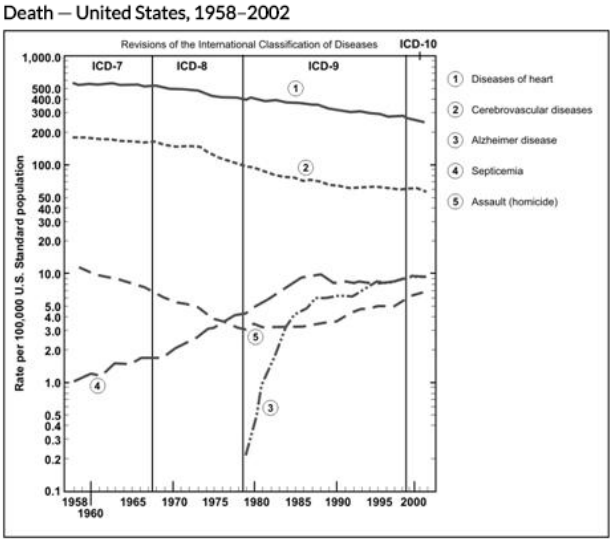


Figure 25: The first medical graph used in the screencast. This example is used first because the indexes on the vertical axis are clear and logarithmic.

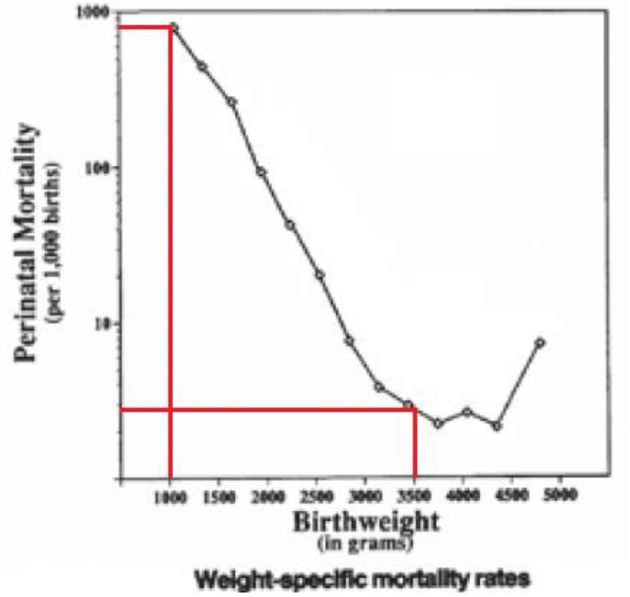


Figure 26: One of the medical graphs used in the screencast, here shown with red lines to help the students read the values, a signalling strategy suggested by Mayer and Moreno (2003)

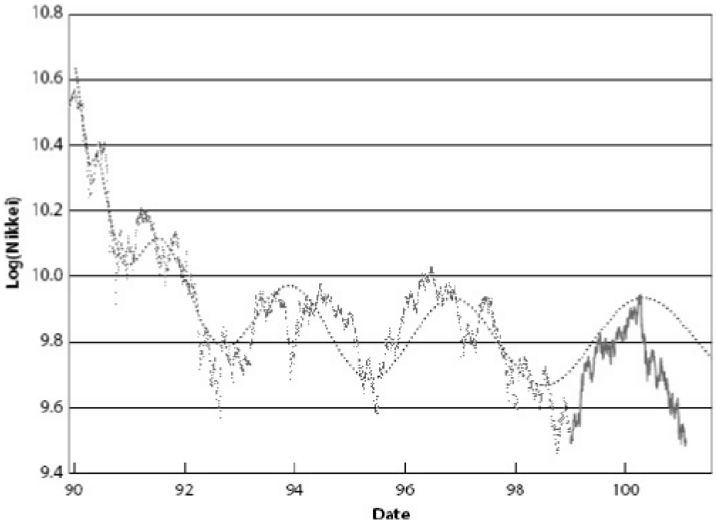


Figure 27: One of the graphs from economy used in the screencast. The objective of including this graph is to demonstrate the semi-logarithmic plots are used within economy. The students are not intended to understand the content of the graph.

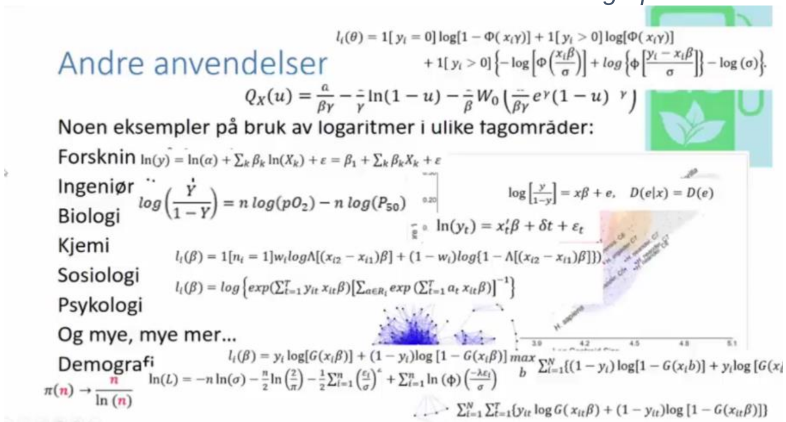


Figure 28: Summary of the breadth of the uses of logarithms, as the screen appears in the end. The intention here is to demonstrate that logarithms are used within many disciplines, and not only in the form of (semi-) logarithmic plots.

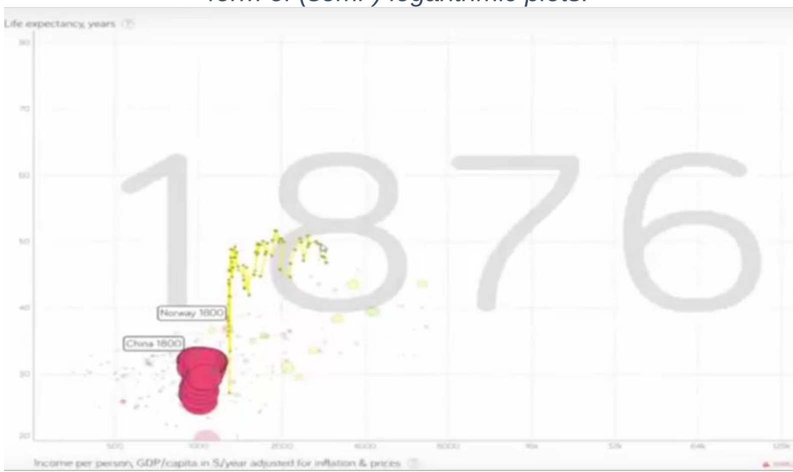


Figure 29: Screenshot from the animation "health and wealth of nations", as it appears for the year 1876. I have highlighted and added tracing to China and Norway. Notice that in all of the semi-logarithmic plots found in Study 1, except this one, the vertical y-axis that is logarithmic. Here the horizontal x-axis is logarithmic, showing gross domestic product per capita, adjusted for inflation and prices. This screenshot also shows how blurry the screencast is at times; is it very difficult to read the entries on the axes, and the country labels. You can see the cursor in the lower part of the number eight.

7.1.1 Equipment

I used Audio-Technica AT2020USB+ Cardoid Condenser microphone to record my voice. I used the software Screencastify Light, a free software from Google, to make the screencast. A colleague edited the screencast with Camtasia.

7.2 The Interview

7.2.1 Research Paradigm

In this section, I discuss how my research is situated within research paradigms and what implications that has for methodological considerations.

7.2.1.1 Epistemology and Ontology

Ontology concerns the question "what is the nature of reality?" (Mertens, 2014, p. 10). I consider my research as set within *interpretivism*. This means that reality is viewed as a human construct, and different people often have similar but not necessarily the same perception of the world (Bassey, 1999). The goal of interpretitive research is to "explore perspectives and shared meanings and to develop insights into situations" (Wellington, 2015, p. 26). Language is then a *"more or less* agreed symbolic system" (Bassey, 1999, p. 43, emphasis in the original) of communication, implying that the same statement can have different meanings for different people.

Epistemology is "the study of the nature and validity of human knowledge" (Wellington, 2015, p. 34). The assumptions of interpretivism has profound implications for the strengths and weaknesses of the study. Everything I observe in the context of the student's life is interpreted by the students in one way, and possibly in a different way by me as a researcher. It is therefore paramount that I try to comprehend as much as I can of the students world, and try to get good and detailed elaborations of the students' statements. Still, I can never be absolutely certain that I have the correct understanding of the student's perspective and this is a major weakness in interpretivist research (Schwandt, 2000; Wellington, 2015).

7.2.1.2 Methodology and Unit of Analysis

Mertens (2005) states that the methodological question is "how can the knower go about obtaining the desired knowledge and understandings?" (p. 10). Within Cultural-historical Activity Theory, the prime unit of analysis is an activity system, and goal-directed actions performed by individuals or groups, as well as automated operations, as subordinate units of analysis that are understandable only when interpreted in light of an activity system (Engeström, 2001). In other words, empirical data are interpreted through what I can learn about the interview objects' activity systems, and what goal-directed actions they are evidently engaging.

7.2.2 Research Design

The empirical data in this research are obtained from interviews. I had ten students participating in the interviews. They were students from the same school and the same mathematics class. They were interviewed in five pairs, and four of the five interviews were analysed and transcribed. Because of time limitations, the fifth interview was not transcribed and analysed. It functioned as a backup, in case one of the first four interviews went technically wrong or did not provide sufficient information.

Bogdan and Biklen (1992) defines qualitative research by five characteristic traits, but emphasises that it is not necessary to exhibit all five. This study fits their definition because all of these criteria are fulfilled; 1) the natural setting is the source of data and the researcher is the key instrument; 2) it is descriptive; 3) it is concerned with process rather than outcomes or products; 4) the data are mainly analysed inductively; and 5) "meaning" is of essential concern (Bogdan & Biklen, 1992).

The study was *instrumental* because it aimed at saying something general about how the screencast was perceived by students in a relevant educational context (Stake, 2000). The focus is on what can be learned from the particular cases (the students), so it can be called a *multiple case study* (Stake, 2000). It is *collective* because I look at multiple student's reaction to the same phenomenon, my screencast (Stake, 2000).

As explained by Jacobsen (2005), the advantages to using a qualitative approach is that you do not need to decide what exactly you are looking for beforehand, and you can get a much more nuanced understanding of the phenomenon than a qualitative approach would yield. It makes it possible to have much flexibility in pursuing things that arise during the investigation otherwise be difficult to uncover. Information that appears during the research can affect the research questions, data analysis, further approach and further data collection as new information can open for new approaches that were not apparent earlier (Jacobsen, 2005).

Case study research is riddled with challenges. It is time consuming, and in the limited scope of this master's thesis, it is impossible to interview many students. Therefore, this becomes an *intensive* study, going deeply into a few cases (Jacobsen, 2005). This affects the external validity. Another major disadvantage that parallels the challenges mentioned about interpretivism, is the amount and complexity of the data, and the human tendency to selectively remember some facts and neglect others. This makes it very difficult, perhaps impossible, to make an interpretation of the data that takes all observations into account (Jacobsen, 2005), not to mention the things that do not surface during the intervention. Meaning can also be lost in the process from the students thoughts to the words analysed in the thesis (Stake, 2000).

7.2.3 Interview Method

The final step in the methodology is to get feedback from students in the target group on the screencast through an interview. The first step is to make an interview guide based on Kvale's criterions (Kvale & Brinkmann, 2015. See appendix 12.6 for the interview guide and a reproduction of Kvale's Criteria) and the structure suggested by Mertens (2014). The interview is semi-structured, that is, I have a set of questions and topics that I want to discuss, but I am open for digressions and have the flexibility to pursue interesting issues that appear during the interview (Wellington, 2015).

To find interview participants, I contacted a teacher at a local upper secondary school. I explained the objective and asked whether I could interview a set of students from his class. He agreed to let me do this. To my advantage, the class were learning about logarithms at the time, and the interviews could be conducted shortly after finishing this topic. I made an agreement with the teacher that he informed the students in advance about the project, giving them time to consider whether they wanted to participate. Then I visited the class on a Monday, asked openly who wanted to participate for an undisclosed reward, and ten students agreed to participate, seven boys and three girls. I talked through the content of the NSD information form (appendix 12.3), handed it out, asked them to sign and collected the signed forms. All ten students signed. I informed them that I would return the following Thursday to start conducting the interviews.

As planned, I returned the following Thursday. I asked the teacher to make interview pairs based on friendship and acquaintances through group work in class. I set up the recording equipment in a neighbouring room and conducted the interviews with the pairs.

I started the interviews (part one) by declaring the purpose of the interview, told them shortly about myself, and what kind of information I was looking for. Then I expressed gratitude for their participation. Then I went on to ask questions about their back- and foreground (part two): why they chose R1 mathematics; wishes, ambitions and goals for further studies, career and future; and general thoughts on mathematics and relevance. In the next part (part three) I asked them if they thought logarithms were relevant to them and if they knew about any uses. Then I showed them the screencast. After the screencast, the students were encouraged to share their immediate thoughts on the screencast (part four). Then I asked questions (part five) about clarity: was anything difficult to understand?; changes: were there anything you think should be different?; relatability: was there something in the screencast to which you could relate?; and motivating: do you think that this can contribute to your motivation for working with mathematics? I use the word "video" instead of "screencast" when I am talking to the students.

In the interview, I tried to ask general, open questions, and get clarifications whenever necessary. I tried to listen carefully to what the students were saying and followed up interesting ideas, opinions and attitudes with further questions. Whenever the student had something to say, this would be the focus of the interview and I would give the respondent time to think, to express their opinions, and allow time for silence if necessary. I would try to avoid any leading questions. The opening questions was about the student and aimed at understanding his/her perspective. I also encouraged the students to be critical of the content and presentation. The interview was piloted with my fellow student writing on a similar topic and our supervisor.

The results of the interviews are presented in chapter 8.

7.2.3.1 Equipment

The interviews were recorded with Audio-Technica AT2020USB+ Cardoid Condenser microphone connected to a laptop and Audacity 2.1 software.

7.2.4 Data Collection, research context and respondents

The interview data were collected in a R1 class in a normal (i.e. public) Norwegian upper secondary school. It can be considered a sample of convenience, because I work in the evening classes of this school, and I am acquainted with their teacher. I did not know any of the interview participants before the interviews.

I decided to interview all the ten students that agreed to participate, so the only selection criteria was whether they themselves agreed to participate.

When the students learned about logarithms in their normal lessons, applications of logarithms had not been emphasised. Their textbook, Sinus R1, presents the Briggsian logarithm, techniques for solving various equations and inequalities with or involving the Briggian logarithm. The natural logarithm is also presented with techniques for solving equations and inequalities. Differentiation of the natural logarithm in covered in a later chapter. Except for one example and one task about compound interest, all the examples and tasks about logarithms are without practical context (Oldervoll, Orskaug, Vaaje, Hanisch, & Hals, 2007).

The students were used to work on tasks in groups. To improve the ecological validity, the interview pairs were put together based on why has been working together in groups and other connections. This evaluation was done by their teacher, the best qualified person for this task. There are possible disadvantages to pairwise interviewing: there may be things they are embarrassed to say in front of peers and comments can be interrupted. Furthermore, the interviews were conducted in the school that they know and in rooms they are familiar with, and I am the one visiting them, not vice versa. Although I am a stranger to them and they are in the presence of recording equipment, there are in familiar settings.

7.2.5 Ethical Considerations

The interviews were conducted in a school where I am employed, but my duties are restricted to evening classes so I had no connection to the interview participants. However, I am acquainted with their teacher and he was in fact my mathematics teacher in my last year of upper secondary. My acquaintance with him was hidden from the students so that this connection would not affect their responses.

The interviews lasted for approximately 20 minutes (including 5 minutes for watching the screencast), and the students were taken out of class for approximately 22-23 minutes, adding some time for setting up the gear and going in and out of the room. During the interviews, the rest of the class were working on tasks. That way, the interview participants did not miss important lecturing. The participants were awarded with a little gift, they could choose between a yellow marker or a reflex provided by MatRIC[4]. All the students chose the marker.

A source of tension can be the fact that I have two roles: I made the screencast and I conducted the interviews. The students will be aware of this, because my voice is in the video. Because of this, they will perhaps give a more positive response then they otherwise would do. However, because of the time limitations in this research, I cannot hide my role as maker of the screencast.

7.2.5 Audio

The interviews were recorded with an audio recorder. Because the interviews are relatively short and divided into smaller chunks, I did not find it necessary to use field notes. The recording equipment probably affected the behaviour of the respondents, and this effect would

[4] MatRIC: Centre for Research, Innovation and Coordination of Mathematics Teaching. A learning community working for excellent mathematics teaching, based at the University of Agder. http://www.matric.no/

likely be stronger with video recordings (Jacobsen, 2005). It would have been possible to make video recordings. This would give access to more details in gestures, facial expressions and body language. The additional data might add some depth to the results, but it would also add a lot of unnecessary information that could create confusion; the analysis would be more time consuming; and the respondents would be more uncomfortable, adding more uncertainty to the data (Jacobsen, 2005). The impact of recording equipment on interview objects is smaller in the younger generation that is used to dealing with technical gadgets (Jacobsen, 2005).

7.2.7 Data Analysis

In Cultural-historical Activity Theory, the unit of analysis is an *activity system, goal-directed actions* and *automatic operations* (Engeström 2001). In my study, the accessible activity systems, activities and operations are those that are described in the statements made by the students during the interview. I will try to answer my second research question by looking at the units of analysis in light of my theoretical framework. The elements that I want to highlight are relevance, a person (subject) or persons (community) perception that something (tool) is useful in achieving the object or motive of an activity, and other forms of feedback on the screencast. Thus, the objective of the data analysis is to identify activity systems, with particular emphasis on objectives and motives, and activities and operations that are connected to objectives and motives. Additionally, I will also identify positive and negative feedback on the screencast.

The interview data were analysed by reading through each interview transcript, interpreting each comment for cues that could enlighten the research questions, particularly the second research question that concerns the students views on the relevance of logarithms, and on the screencast. Then these interpretations were categorised into categories like "motives in classroom activity system"; "knowledge of applications of logarithms before seeing the screencast"; "feedback on content"; "feedback on level of difficulty"; "technical feedback" and finally "additional results".

7.2.7.1 Transcriptions and Transcription Key

The first four interviews were transcribed in their entirety (see appendix 12.8.1-4 for transcriptions). The fifth interview functioned only as a backup, in case one of the first four did not provide sufficient information.

I used a key for the transcriptions (see appendix 12.7). I developed this key during the transcription process, adding new symbols as the need arose. Anonymised names with index letters following the alphabet are used for the interview objects, with feminine names for girls and masculine names for boys: André, Bjørn, Christian, Daniel, Emilie, Fredrik, Gjertrud and Hilde. Gender is preserved because some authors have found gender differences in interests (Schreiner & Sjøberg, 2010).

The comments that are used in the thesis are highlighted with bold text in the transcriptions to make them easier to recover. Because the interviews were conducted in Norwegian, the transcriptions are written in Norwegian too. The comments that are used in the thesis have been translated into English, and the original Norwegian text in in the appendixes.

7.2.8 Validity and Trustworthiness

This section is concerned with evaluation of quality of the research. Evaluation of quality in qualitative research is difficult, and there is little consensus on what the evaluation should consist of (Corbin & Strauss, 2008). The most commonly used criteria used in mathematics education research are validity and trustworthiness, so I will use these.

7.2.8.1 Validity

"Validity refers to the degree to which a method, a test or a research tool actually measures what it is supposed to measure" (Wellington, 2015, p. 41). This question is often divided into sub-questions. I will here discuss internal, external and ecological validity.

The question of internal validity, "the extent to which scientific observations and measurements are authentic representations of some reality" (le Compte & Preissle, 1984, p. 323, quoted in Wellington, 2015, p. 42). I am not able to look into the minds and thoughts of the students. Yin (2014) argues that "[t]he strength of a cause-effect link made by a case study, in part determined by showing the absence of spurious relationships and the rejection of rival hypotheses" (p. 239). There are indeed possible rival hypotheses to several of the results: 1) It is possible that the interview objects are "nice to me" and therefore do not want to say something negative about the screencast. This effect was strengthened by the fact that I have a double role in the interview: I am both the maker of the screencast, and the interviewer. It would have been advantageous for the validity of the results if I had hired another person to either make the screencast or do the interviews. This option was not feasible within the time limits of this project because this person would need to obtain specialized knowledge. 2) The students wants to get finished quickly so that they can return to their lesson. This is a possible reason why some students said little in the interview, particularly the last part. Other students are less likely to think this way, for example Daniel (group 2) who concluded the interview by saying "this was fun. We need some variation in math classes!" In addition, the interviews were conducted while the rest of the class were solving exercises, so the interview participants were not missing important theory. Flegg et. al. (2012) found that the students in their study reported that they found mathematics relevant to their career after having worked with real-world problems when they were surveyed, but they gave a different response in follow-up interviews, with some seeing no relevance of mathematics to their future career at all. This problem is avoided by interviewing the students, and indeed, I do find some students that don not see mathematics as relevant to their careers, even after having watched the screencast.

The question of external validity is in essence "the extent to which the findings or conclusions of a piece of research could be generalized to apply to contexts/situations other than those in which the data have been collected" (Wellington, 2015, p. 345). Intensive qualitative studies are inherently weak on external validity (Jacobsen, 2005). A wide range of cultural factors affect the students, including but not limited to their mathematics education history: what have they learned about logarithms?; economic background: students from poorer backgrounds have different preferences than those from richer backgrounds (Schreiner & Sjøberg, 2010), and this effect may exist within countries. All the students are attending the same school, but they may have different socio-economic backgrounds. Due to time constraints, I have not had the opportunity to repeat the investigation at another school. The number of participants (n=8) gives a relatively narrow base on which to say something general about how the screencast is viewed by students in the target group (those attending

R1-classes in upper secondary education in Norway). Concordance with results from similar projects (Loch & Lamborn, 2016; Mustoe & Croft, 1999; Gebremichael et. al., 2011, 2014) enhances the analytical generalizability, as do the fact that the eight students represent a broad range of different objectives and motives (more on that in section 8.1).

Ecological validity refers to the extent to which the results can be generalized from the conditions in the interview setting to other contexts (Mertens, 2015), like the mathematics classroom. The mere presence of recording equipment can affect the behaviour of the participants (Jacobsen, 2005), as well as my presence as interviewer (Mertens, 2015), the fact that they were taken out of the classroom and into a different room, and many other factors has an impact on ecological validity. To preserve some of the social factors of the classroom, the students were grouped into interview pairs based on previous acquaintance. Furthermore, they are in the school that they know and in rooms that they know. I believe this made the student feel more at ease during the interview. Another factor that can be contribute to ecological validity, is the fact that I, the interviewer, am relatively young and that I, too, took R1 mathematics when I was their age. Thus, I have an insight into their world that may be advantageous.

7.2.8.2 Trustworthiness

Trustworthiness is about whether the methods employed "can persuade an inquirer persuade his or her audiences (including self) that the finding of a inquiry are worth paying attention to, worth taking account of?" (Lincoln & Guba, 2985, p. 290). To ensure that the transcriptions are accurate renditions of the interviews, they were written within two days after the interviews were conducted. By transcribing the interviews in their entirety, I ensure that the participants' voices were reproduced accurately. I have also been careful in including the exact wording of the questions I asked, because my choice of words can affect the meaning of the question.

The research tool, the screencast, can be used again for evaluating students' response[5]. The interview was semi-structured, meaning that it can not be repeated exactly. The interview guide is found in appendix 12.6. With that basis, I argue that it is possible for other researchers to conduct a very similar interview to test my results.

[5] The video can be seen here: https://www.youtube.com/watch?v=nWQubl3D_1g
A brief summary of the video, without the audio narrative, can be found in appendix 12.5

8 Study 2: Results and Analysis

In the following sections, I will present the results from the interviews that can provide insights into the second research question, and these results are analysed in terms of ChAT. Section 8.1 is concerned with what the students said before seeing the screencast. I focus on why they chose R1 mathematics, ambitions for further study and career, and what they think about the relevance of the content of R1, particularly the relevance of logarithms. In section 8.2, I present the results obtained after showing the screencast, and focuses on the students' reception of the video and on the student's statements concerning the concept of demonstrating relevance. The complete transcripts are in Appendix 12.8.1-4. These are written in the original language, Norwegian, while the quotations included in this chapter have been translated into English by the author. I have tried to maintain the students' language by using contractions. Triple dots (…) indicate that something is cut out. Italics are used to indicate emphasis on a particular word. The Norwegian work "realfag", which is an umbrella term for the natural sciences, technology, engineering and mathematics, is translated as 'STEM'.

8.1 Interview before Watching the Screencast

All the students are engaging in the activity system of the mathematics classroom, with the same rules and available tools (although they might use the tools differently). The community is essentially the same for all of them, the only difference being that the list of fellow students does not contain the student in question. The division of labour may differ; cooperative learning in fixed groups is part of their didactical contract, and it is natural that the students take different roles in this system.

On the issue of objectives and motivations for participating, the perspectives depend more on the individual. On wishes and ambitions for future studies and career, the responses were, for example:

Bjørn:	I'm very unsure about further education, but I'm thinking that it is very likely that I will do some form of college [or university] education, and that it will most likely be within the STEM-fields.
Interviewer:	Yes
Bjørn:	But I don't know much more than that, really, I'm a little unsure about it.
	…
Interviewer:	Yes. It's not like you have been thinking about engineering or medicine, you haven't been thinking about that?
Bjørn:	No, it's like, they are both alternatives that I've been thinking of, but I don't know. I haven't settled with anything yet really.

Bjørn has no clear plans for his future studies or career, but he is heading in the general direction of the STEM-fields. André, being interviewed together with Bjørn, adds

André:	It's quite likely that it'll be something related to STEM-topics.

When I ask them if they could imagine studying something different, they both have more to add:

André:	I'd study sports!
Interviewer:	Yes
Bjørn:	Yes, it could've been sports for me too if I had the opportunity. But it could also be social anthropology or psychology, those are things that I'm also interested in.

Many of the students in this class are considering university studies that require R1 and/or R2 mathematics, and they do not consider study programmes which are traditionally not connected to mathematics, like psychology. Most students are quite specific, having a title of a study programme in mind, while others are have decided on what institute they want to attend:

Emilie: I don't know what I want to become, but I'm taking IB next year and then perhaps NTNU

In the cases where they want to study something related to STEM, the objective of taking R1 mathematics must be, at least in part, to fill the requirements. This is likely also true of those who do not know what to study and are taking R1 mathematics to keep all opportunities open, like Fredrik:

Fredrik: I just try to keep all the doors open.

Gjertrud also has many different goals for tertiary education:

Gjertrud: I think it will be something within STEM, like biology. But I also want to study psychology, I think everything is very exciting and I can't decide!

She is considering studying biology, but also psychology. Other students do not have any idea at all as to what they want to do after upper secondary school:

Hilde: Nothing

None of the participants mentioned studying or working with economy, business or administration. Some of the students perform well in mathematics and can add that part of their objective with choosing R1 was to get a good grade.

Bjørn: I like mathematics and get good grades

Another element in Fredrik's decision to choose R1 mathematics lies in his background:

Fredrik: [the reason I chose R1 mathematics] is kind of a continuation. I always performed well in maths … and 1T went well, so [R1] was the natural choice.

Fredrik's choice of R1 was mediated by his previous performances, his history. Better grades are improving their chances to get into any particular study programme. Daniel says that pressure from his parents and peers affected his choice:

Daniel: It's [pressure] from parents of course, and also some from my friends. Many of them are performing very well. I want to be on the same level, you know.

This pressure comes from the activity system of his family and the activity system of his friends. Some students state ambitions that are set further into the future:

Daniel: I suppose [career aspirations and further studies are] about having a relatively high-educated job from which I'm well off. And fun. I think that's very important.

Emilie: I can help my kids, my little brother

Among Daniels motivations with choosing R1 is getting a well-paid job requiring "relatively" high education. Emilie has a different motivation in helping her siblings and future kids with mathematics, which is not within an activity system of a future study or workplace, but within the activity system of the family.

The students' perception of the relevance of mathematics is mediated by the way mathematics is taught and the structure of the school system and system for admission into tertiary education:

André: I think [mathematics] mostly about … just having the foundation for further study.

Bjørn: I think that mathematics is really only about testing understanding and testing how the mind can assemble patterns and stuff. … I've never thought about logarithms as relevant in, like, a direct context, like if I were out some place and in a situation… then I'm thinking "wow, now I must think logarithms to figure out what to do next… but like with everything, it's about exercising the mind, IQ-testing, testing, see things in context…

School mathematics is largely centred on testing and grades and the grades are in turn the foundation for admission to further studies, and this is how André and Bjørn perceives it: they are learning mathematics because it can be useful in further studies and Bjørn thinks it’s a convenient method for testing skills in reasoning and intelligence. In their view, the mathematics they are learning is not relevant in its own right; it is only relevant as a tool for achieving other goals. Although many of the students report similar feeling on the relevance of mathematics, Daniel has a different view:

Daniel: I think that a lot of the mathematics we're learning now, I'm often feeling that it's a little superfluous, maybe that I don't see any uses for exactly this kind of mathematics. But of course, I see that many topics can be useful. Like what we're learning about now with differentiation, I think finding rate of change everywhere, can be relevant. But there are also the unnecessary things. … [logarithms] is actually one of the things that I'm not so sure whether is useful or not.

Daniel think that parts of the mathematics curriculum are not useful, but he point at differentiation as something with use value. He is unsure whether logarithms are useful. Gjertrud thinks that the mathematics she is learning now will be useful in the future, but she does not know how:

Gjertrud: I really feel that what we're learning is, like, further, that we're learning something we can get use for … Just like when you learned the multiplication table. Why do we need to learn multiplication? Now I use it all the time

Her perception of the relevance of mathematics is mediated by her experiences with the subject: she views mathematics as useful, but that the usefulness will only become clear later. Only one student knows about any uses of logarithms:

Fredrik: It's used in pH, that I know!

This perception is also mediated by the school activity system because he goes on to say that he learned about the role of logarithms in pH in chemistry class. The other seven students had nothing to say on uses of logarithms.

To sum it up, the students are engaging in the classroom activity system with several motivations. Most, but not all of the students have the motivation that they want to go on to tertiary education. Some of them have decided that they want to attend a study programme within a particular direction, like engineering or something STEM-related, while others are undecided on this point. None of the students have decided on a particular programme. Some students have a motivation set further into the future, like Daniel who wants a fun and well-paid job requiring a "high" education, and Emilie who reflects on her role as a future parent and how she can help her kids with mathematics homework. Their peers and family may have mediated these ambitions; perhaps Daniel comes from a family where status and income is highly valued, and Emilie comes from a family where parents spend considerable time helping their children with homework. Among the students that have not yet decided on whether they want to attend tertiary education at all, or what direction they want to go with their studies, a commonly stated motivation for attending R1 mathematics is that it "keeps all the doors open"; without R1 mathematics, many study programmes within STEM, economy and business are excluded or difficult to attain. This motivation is mediated by the rules of admission into tertiary education. This structure is illustrated in figure 30.

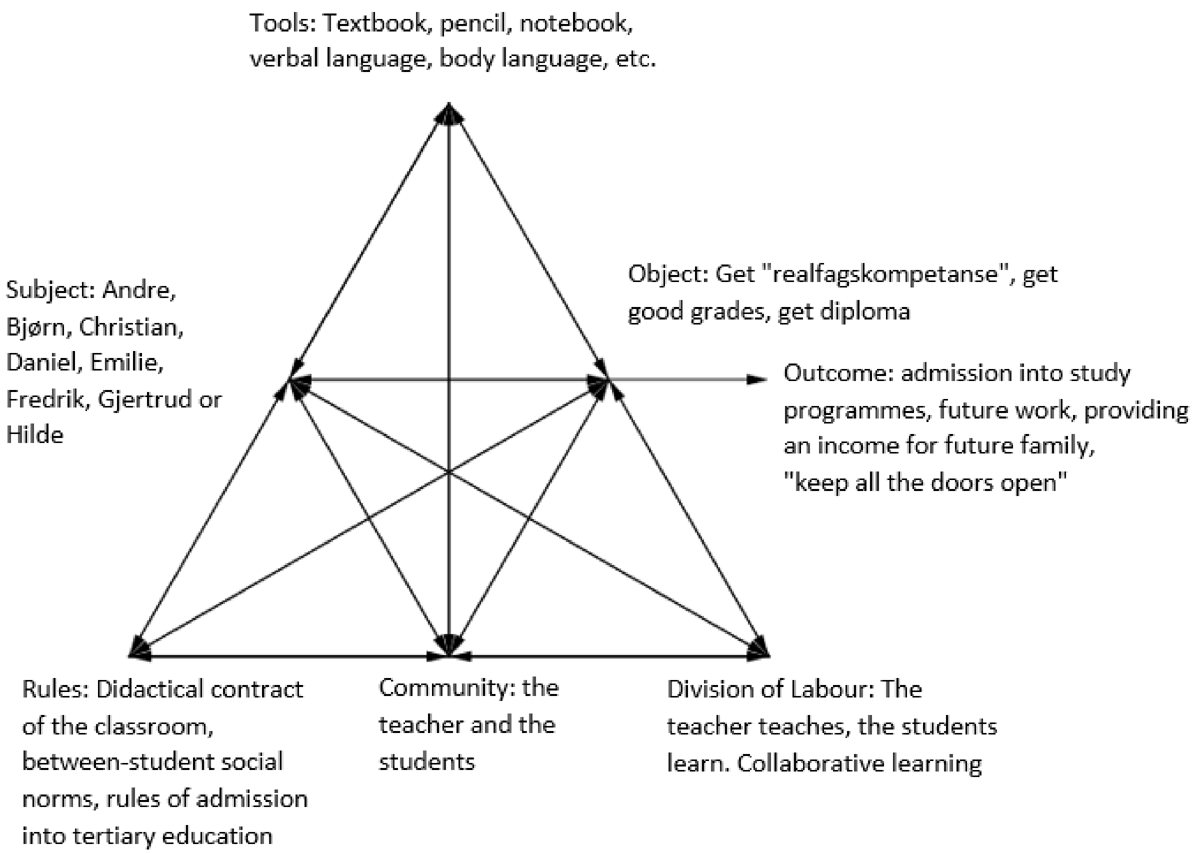


Figure 30: The classroom activity system

8.2 Interview after Watching the Screencast

This section focuses on the response the students gave after seeing the screencast. The results are categorized into feedback on the content of the screencast (8.2.1), feedback on the level of difficulty (8.2.2), technical feedback (8.2.3) and additional results (8.2.4) that do not fit directly into any of the above categories.

8.2.1 Feedback on the Content of the Video

André comments on what he perceived as the main message:

André: The main thing was perhaps… that… how you could… in those diagrams [log-plots], show much better how the differences really are

He thinks that the main use of logarithms is in logarithmic and semi-logarithmic plots, as demonstrated in the screencast. Bjørn adds to this, saying

Bjørn: If you are to interpret information as a citizen, then it is very useful to look logarithmically on things, how we can demonstrate a much more realistic connection.

Bjørn argues that "looking logarithmically in things" is useful for citizens. It is unclear whether Bjørn realizes *when* (semi-)logarithmic plots are useful and not, but it appears that André caught this lesson:

André: It's also very useful that you can compare various diseases that are completely different

The keyword here is "completely different". None of the students ever uses the phrase "orders of magnitude", even though this phrase is used in the screencast. "Completely different" may be André 's way of expressing this kind of difference. On the depth of the coverage, André says

André: You could of course go into each topic, every profession and such, but that would take extremely long time.

He appreciates that the screencast is a compromise between depth and width of the coverage. I asked André and Bjørn about how they can relate to the content in two different ways, first openly asking openly about how they can relate to the content, prompting Bjørn to say

Bjørn: I suppose it will always mean something. Not that perinatal mortality in the world is so important to me yet, I don't have an infant weighing one kilogram … We are learning a lot about demography in social studies, and knowing about such a comparison between economy and longevity is… it is a very practical application considering what I'm currently learning about in school.

It would appear that Bjørn find the content relevant to other school subjects, particularly social studies. André says nothing. When I ask the same question in a different way, the response is markedly different:

Bjørn: It looks like an approximate top list of professions that could be relevant…

Despite Bjørn's moderate response to the previous question, the list of fields where logarithms are applied is like a "top list" of relevant professions to him. André says nothing about how he relates to it.

Daniel and Emilie has some remarks on the screencast and mathematics education:

Daniel: It does something that the school doesn't, that is, enlighten why we need these things. That's actually something I think of as a *major problem*.

Emilie: I actually think we should have more of this in math class

Not only did he find the screencast very "good and informative", it also highlights what he considers a "major problem" with school, connecting theory with authentic applications. Emilie, too, thinks that mathematics classes needs more emphasis on relevance. Christian is not happy with the content:

Christian: The examples are very… historical, but I don't see any practical needs, that I would have used for example in a regular man's day-to-day activities.
Interviewer: No. What are you thinking of?
Christian: I wouldn't make a graph at work.

It would appear that he finds none of the examples relevant, and perhaps the emphasis on graphs was unfortunate for him. The screencast failed to bring up any examples that convinced him that logarithms are relevant to him. Perhaps a heavier focus on applications from engineering and science would be more captivating for him. His mention of day-to-day activities is also interesting; perhaps it would be better if the screencast clearly said that logarithms are not directly useful in cooking, driving and other day-to-day activities. Furthermore, his statement can be interpreted to imply that because the screencast did not convince him that logarithms are relevant to him, then it is reasonable to assume that logarithms are *not* relevant at all. However, Christian follows up with an interesting statement:

Christian: I think you demonstrated… that we get use for logarithms in a nice way… that it has applications at all.

Although the screencast failed to make logarithms relevant to him, it did establish to him that there exist applications. His thoughts on videos about the relevance of topics in mathematics in general follows the same pattern:

Christian: I'm thinking that if you connect each formula with an application of logarithms, examples, so you can see areas of applications, a practical area of applications so you need to think around the formula, instead of seeing just another logarithm formula.

Again, he wants the instruction to be technical and detail-oriented, not concerning logarithms in general but connecting each formula with an application. Emilie asks follow-up questions about the screencast:

Emilie: How does it work in psychology and sociology?

After a brief explanation, she exclaims "cool!" Before the screencast, Fredrik only knew of one application of logarithms. His initial thoughts indicate otherwise:

Fredrik: It was like I expected, mostly about presentation of statistics and such. Provide an overview; get it in a transparent system.

It is not clear whether he knew about (semi)logarithmic plots prior to watching the screencast and did not recall, or if he did not know and for some reason wrongly believes he knew.

It appears that the list of fields where logarithms are used was intriguing to Gjertrud:

Gjertrud: I can use it in biology, and… with psychology I got a little… what would that be… sociology yes… then I was like "oh, you can use it there, too". But once you've mentioned it, I realize that you can use it, you've got many graphs and… I don’t know. But I dunno, can relate to it now since I'm about to choose [higher education] now… it's nice to know that the maths means something.

However, it is possible that she, too, has gotten the one-sided view that logarithms are only used in graphs.

8.2.2 Feedback on the Level of Difficulty

Daniel explains: "Perhaps [the animation from Gapminder] was a little advanced".

Emilie:	I think it was difficult to understand how the graphs worked…
Interviewer:	Yes
Emilie:	or why they were logarithmic.

Emilie found the connection between the graphs and logarithms unclear.

Gjertrud:	It was nicely explained. But I think I need more expertise to be able to… for instance… I did not know what that was [real numbers].
Interviewer:	Yes
Gjertrud:	Know some more words.

Gjertrud found parts of the screencast difficult because there were some unfamiliar words, at least real numbers was an unknown term to her. At least two students did not recall what the natural logarithms is.

Hilde, like Emilie, did not understand the connection between (semi-)logarithmic plots and logarithms.

8.2.3 Technical Feedback

On whether anything could be different in the screencast, Fredrik says

Fredrik:	I think it was nice. But I'm thinking that when you're not talking about a graph, you can let it be visible for a moment. Because when you're done talking, it's nice to have some time to reflect over what you said while looking at the graph.

Fredrik thinks that the graphs should linger on for a few moments after being discussed. Hilde, too, comments on technicalities:

Hilde:	Some of the pictures were a little unclear

The resolution of the pictures in the screencast is not very good.

8.2.4 Additional Results

Several students commented on how the screencast can affect motivation for learning mathematics:

Bjørn:	I don't generally struggle with my motivation in mathematics, when [the teacher] explains, I understand the most of it, and I don't have to work hard with it.

Bjørn connects motivation with achievement, and argues that because he achieves well with little effort in mathematics, he does not need a motivational boost. Five other students have a different view on the screencast's effect on motivation:

Daniel:	I think we need to know what the things we are learning can be used for. It can also be very positive for motivation, actually.
Emilie:	I think [it can be motivating]

Fredrik: I agree [with Emilie]. Because it's often a lot of memorization in maths, without knowing what you can use it for.

Gjertrud: If there were a video like this for each chapter, and the teacher showed it when we began, like, "here's the reason we're learning about this topic", then you get some motivation, "okay, this is useful, we can use this!" … That would be nice

Hilde: I agree very much [with Gjertrud] … I think it would be very important, too

Daniel, Emilie, Fredrik, Gjertrud and Hilde, on the other hand, finds it very motivational to learn about the usefulness of logarithms. Daniel, Fredrik and Gjertrud clearly states that they know little of the usefulness of mathematics and that they want more of it, and that it will be motivating for learning mathematics.

Hilde comments on the idea of presenting applications of mathematical topics:

Hilde: But it's almost like I think teachers should say more often, that "this can be used for that". Because it helps us a lot more in what we… If I think logarithms are very difficult, it can be a hint that I ought to choose something other than chemistry… It's like… I don't know how to explain it… but the entire chemistry-bit isn't logarithms, but for example pH and stuff is a logarithmic scale. Just so that I know a little more about where the topic at hand is used.

Put short, her argument is that if logarithms are used in a field and she finds logarithms challenging, then this is a reason to avoid said field. She mentions that pH is a logarithmic scale, this is likely something she learned during the screencast since she did not bring it up when I asked about knowledge of uses of logarithms before showing the screencast. Asking for clarification, I ask:

Interviewer: So it can almost function as a warning… "Here there be logarithms"?

Hilde: Not always a warning…

Gjertrud: More like it's actually a reason you're doing this… you're not sitting here because we don't like you.

Notice that Gjertrud interrupts Hilde before she completes her statement. She does not want to use the word "warning". I assume that she wants to soften her friends words.

Emilie has an interesting view on how she relates to the content:

Emilie: I think it's very nice to get to know this kind of thing. People always ask "what do you need math for, really?", and it's really fun to actually get an explanation to it.

To her, it is not about providing an answer to that question for herself, but to other people asking "why do *you* need mathematics?", a third way of phrasing the relevance question.

What we see from the first part of interview is that, generally, the students have ideas about their futures, that in their classrooms they learn little about the relevance of logarithms, that the screencast assisted the students in seeing more relevance in logarithms and that they were positive about learning about this relevance.

9 Study 2: Discussion and Conclusion

The classroom activity system has many voices and perspectives; the different subjects, i.e. the students, all have different motivations for engaging here. The background for the choice of participating here is also different. Many students chose R1 mathematics because it improves their chances of admission into a particular study programme. Other backgrounds includes peer and parent pressure and undecidedness: many of the interviewed subjects stated that they chose R1 in part because they do not know what they want to do, and do not want to exclude any options that require R1 and/or R2 mathematics. The mathematics classroom activity system is indeed multivoiced.

Interestingly, many of the stated motivations for engaging in this activity system are activity systems in their own right, or *imagined* activity systems, set in the future. When Emilie talks about helping her younger brother with mathematics, she is talking about a family or siblings activity system. This system is arguably a different on from that of the classroom because it consists of a different community, it has different rules and different mediating artefacts. That does not mean that these two systems are not interconnected; Emilie brings impulses from her family into the classroom and vice versa. The activity systems are ecologically interdependent and subunits of the larger activity system of the Norwegian society; activity systems are embedded in each other and people are naturally engaging in multiple systems. It is not a great leap, then, to imagine oneself in other activity systems in the future. This is exactly what many of these students do: Daniel is talking about getting a highly educated and well-paid job. Interpreting this into activity theory, part of Daniels motivation with engaging in the mathematics classroom activity system is to attain higher education, leading to a high-paying job (Figure 31). The structure of the higher-education system is perhaps unclear to him; he does not know what he wants to study, only that he wants to study something that can lead to a well-paid job.

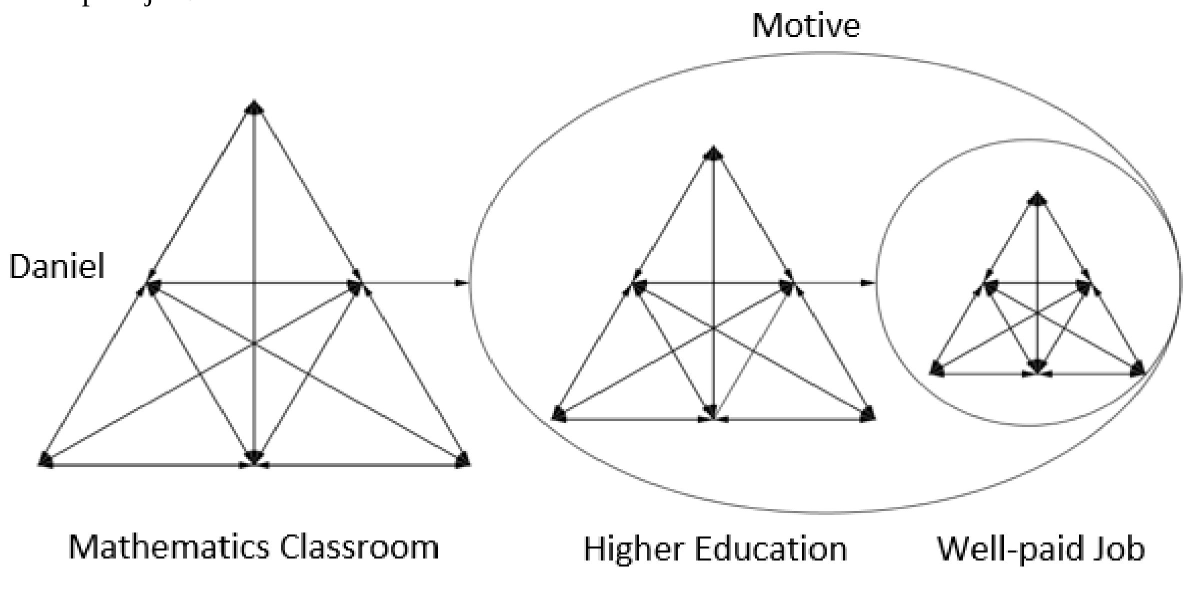


Figure 31: Illustration of Daniels motivations. The activity system of the well paid job is depicted without an arrow for outcomes, since he did not state any and it is possible that he has not disclosed his reflections upon what outcomes he gets from having a "fun, well-paid job requiring a "high" education. The activity systems 'Higher Education' and 'Well-paid Job' are not activity systems in their own right, they are imagined activity systems set in the future.

With motivations like this, where is the *relevance*? Obviously, it is important for Daniel to attain good grades, enabling him to select the best study programmes. So getting good grades is part of his objective when he is engaging here. Making a particular mathematics topic relevant means making it appear helpful to him in achieving his object. In all the cases, the motivations for taking R1 mathematics were set in the students foreground, at least in part. The exception is Emilie, who states motives in her current situation: helping siblings with homework, and in the foreground, attending the International Baccalaureate (IB) programme and studying something STEM-related at NTNU. Factors from the student's background rarely surfaced in the interview. Two exceptions are Bjørn and Fredrik, who states that their previous relation with mathematics affected their choice of R1. In Bjørn's case, he always "liked" mathematics, and Fredrik always "performed well" in mathematics. While some of the reasons for choosing R1 mathematics were set in their background, the students *motivation* is always set in the future, like Skovsmose (2005) argues. The reason why previous performance and "I liked mathematics in the past" are not motivations, is that they are connected with different motives set in the future: "I always performed well in mathematics" is not a reason in itself for choosing the most difficult course available. Extrapolating this statement into the future by expanding into "I always performed well in mathematics, and I believe I will continue to do so", implies that the student believes that s/he will continue to get good grades, and there is the objective. This can in turn be connected with a motivation: admission into a particular study programme or a job satisfying certain criteria, like "well-paid" or "high status".

The results show that the students experience a tension caused by the amount of mathematical detail they want from the video; some students want there to be more mathematical details, even connecting "*practical applications*" with each "*mathematical formula*". Others are satisfied with the amount of mathematical detail, adding that a more detailed description would require a much longer video. This reflects well on the results from Mustoe and Croft (1999) who argues that too much emphasis on mathematical detail drives the focus away from the application. It also looks like several of the interviewed students are left with a one-sided view, that most of the applications of logarithms are concerned with graphical representations. This, too, has a parallel in Mustoe and Croft: they argue that a too simplistic mathematical model can offer a "false prospectus and mislead students into *believing that the only mathematics which they require in their studies is at a low level*" (p. 469, emphasis added). The screencast, presented as an answer to the question "why do I need to learn about logarithms", functions as a mediating artefact to this precise task, and too much emphasis on one aspect of the applications leads the viewers into believing that this particular aspect may be more important or dominant than it really is. This may be the biggest challenge in making educational material, about the relevance of mathematics or the relevance of a mathematical concept. The same observation has been made by other authors (Mustoe & Croft, 1999; Loch & Lamborn, 2016), strengthening my assertion.

One of the students, Gjertrud, expressed her impression that mathematics is relevant to an unknown future, similar to findings of Gebremichael et. al. (2011). Interestingly, several of the students also think that mathematics is taught to *test* the student's ability to reason, without being directly relevant to any concrete situations. Following this line of thinking, part of the objective of choosing R1-mathematics is to *prove* that you are sufficiently skilled to *deserve* a spot in a particular study programme. This may be because the structure of the educational system is mediating the student's perception of the reason why the curriculum is the way it is: a) the admission system is based on merits, that is, grades. Therefore, b) the curriculum is made only to assess students. Thus, c) the content of the curriculum is only relevant for getting grades. This line of reasoning is of course flawed because assertion b) does not follow from premise a); the curriculum is designed to cover many needs, *including* to be an assessment tool, but also to *prepare* the students for their future activities.

Emilie also stated that with this content, she could explain to her peers why she is taking R1 mathematics. Thus, the question of relevance of mathematics can be on behalf of the person learning mathematics (why do *I* need to learn about this?), or it can be on behalf of the *peers* of the person learning mathematics (why do *you* need to learn about this?).

The results of Study 2 demonstrate two ways in which the presentation can be counter-productive. a) Christian did not find any of the examples relevant, and this could potentially imply that logarithms are not relevant to him at all, only relevant insofar that they are necessary to achieve a certain grade. If he perceives the video as trustworthy, meaning that actually is an explanation to why *he* needs to learn about logarithms, and the video fails to present anything that is relevant to him, then the video mediates an impression to him that logarithms are *not* relevant to him (figure 32a). Flegg et. al. (2012) also found that some of the students in their study did not view mathematics as relevant to their career and study, but the authors did not attempt to demonstrate relevance. However, Christian adds that the screencast did answer the general justification problem, "why do we need to learn about logarithms" (Wedege, 2009), when he said that the screencast did demonstrate that logarithms has applications "at all". Kember et. al. (2008) also found that if the material failed to demonstrate that the material is relevant to a student, then the material becomes demotivating. Also b) the, other way in which the screencast can be counter-productive is demonstrated by Hilde: if a student is struggling with a concept, and learns that this concept is relevant to a certain activity, then this relevance provides a reason to avoid that activity (figure 32b). This is very similar to findings by Loch and Lamborn (2016), who found that some of the students in their target group viewed the video as a "scare campaign" (p. 11).

In summary, the presentation will represent the answer to "why do I need to learn about this mathematical topic?", as seen from the students perspective. Although the students are very positive about learning more about the relevance of logarithms, several pitfalls exist and difficult compromises must be made when a mathematics educator is talking about the relevance of logarithms. The activity system of the R1 mathematics classroom that was investigated here clearly demonstrates that the students are multivoiced. They have different backgrounds; different motives; and they experience the mathematics differently. These conflicting perspectives leads to many challenges. a) What is relevant to one student may not be relevant to another, meaning that the scope of the presentation must be broad. b) The students have different preferences to the content of the presentation: some students wants to see detailed technical descriptions of the process of using logarithms in particular contexts, whereas other are intrigued to learn about the broadness of the applications of logarithms. These two aims are incompatible within the recommended time frame of an educational video, so it is necessary to make a compromise. Furthermore, if the video adds too much weight on a particular aspect, this is likely to lead to a one-sided view among the students, that logarithms are *mostly* or *exclusively* used for this particular purpose. Finally, the video can work against its purpose, either deterring students from pursuing a particular study programme or career, or telling student that logarithms are not relevant to him/her.

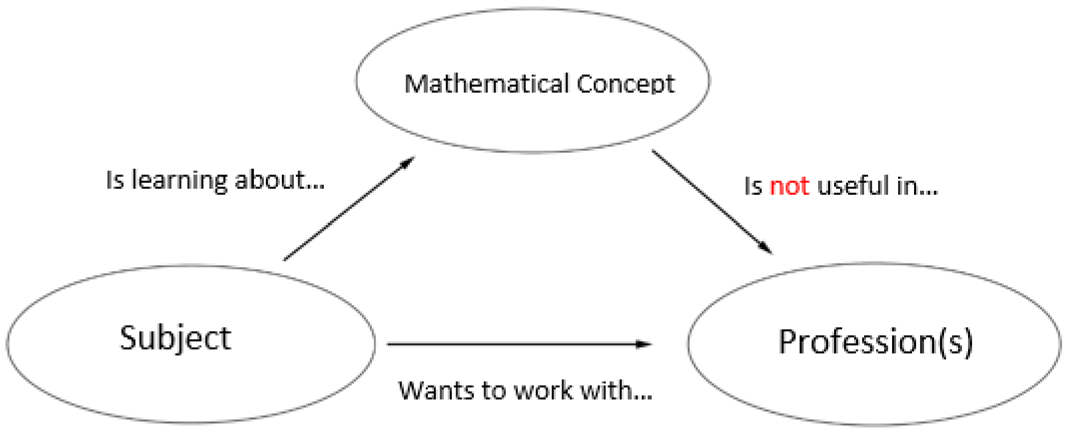


Figure 32a: Demonstration of relevance being counter-productive: the video fails to establish relevance because the mathematical concept is not connected with the student's job wishes.

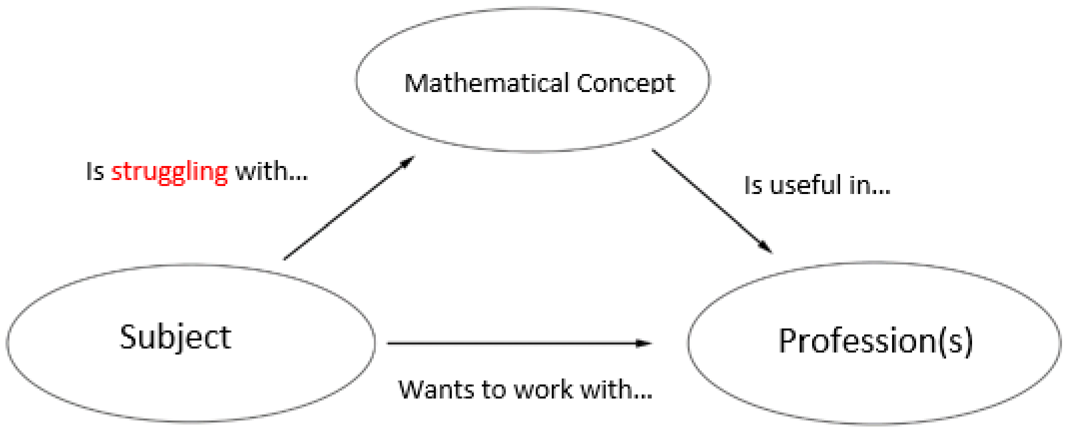


Figure 32b: Demonstration of relevance being counter-productive: the video succeeds in establishing usefulness of the mathematical topic to a profession that the student wants to work with, but the student is struggling with the mathematical concepts and is therefore deterred from pursuing the profession.

9.2 Room for Improvement

The results of Study 2 reveal several things that can be improved, with the screencast and with the interview. In the following section, I use the word "presentation" instead of video and screencast because it is not granted that a video is the ideal format for presenting material aimed at demonstrating the relevance of mathematical concepts.

9.2.1 Improvement of the Presentation

As mentioned, the results demonstrate that students in the target group know little about and want to know more about the uses of logarithms, but that there are different ways in which the presentation of this information can go wrong. In the following section, I will discuss each these, and propose ways in which they can be remedied.

The question of "why do I need to learn about logarithms" begs for an explanation of the relevance of logarithms. Inherent in this question are three sub-questions: by *whom* are logarithms used, *how* are they using logarithms and *why* are they using logarithms.

I contend that the most important issue here is by *whom* are logarithms used, because this is a direct connection between the mathematics classroom activity system of the students (I am learning about logarithms but I do not know why) and the student's *motivations* (in the future, I want to work with *this*). If the presentation manages to present a broad range of *identities* (e.g. engineers, medical doctors, parents, etc.) to whom logarithms are useful and these identities can successfully be connected with the students' motivations (André want to become an engineer), then relevance is easily established. The challenge here is to establish a broad base of identities to whom logarithms are relevant, and in my research, I found many uses of logarithms within study programmes and professions. Another issue that arose here is that if a student is struggling with logarithms and logarithms are useful in a profession, then this profession should be avoided. The only way to avoid that problem is to avoid stating that logarithms are useful within the professions and study programmes that these students are considering going into. Whether it is desirable, to obscure such connections, is doubtful.

The second question is *how* logarithms are used within the different fields. In my screencast, I gave much emphasis to the use of logarithms in (semi-)logarithmic plots, because these were abundant and easy to communicate, and other applications were mentioned and shown as pictures, but not explained. However, as discussed, this led to negative, unforeseen consequences. The most common negative consequence was that this led to a one-sided view that logarithms are used mostly or exclusively in logarithmic plots. This could be avoided by going into more detail on at least one other form of application, for example the use of logarithms to calculate compound interest. Another negative, unforeseen consequence of the emphasis on plots is that one student found graphs, presumably also plots, irrelevant. Despite the fact that he is interested in engineering and that engineering was mentioned as one of the areas where logarithms are used in different ways, the focus on plots led him to think that logarithms are only useful in plots, and since these are irrelevant to him, it can be inferred that logarithms are irrelevant to him.

The explanation to *why* logarithms are used in logarithmic scales and (semi-)logarithmic plots did generate a few comments, and several students commented that they did not understand the role of logarithms in the graphs and plots in the screencast. Another issue here is that the screencast contains no explanation to how or why logarithms are used in other contexts. Some students wanted an explanation to why the cardinality of real numbers equals the cardinality of positive real numbers, but appeared satisfied when I explained that it is too complicated to explain with the time we have. Furthermore, the students were divided on how much mathematical explanations they want. A possible way to remedy this issue is to have a closer connection between the lectures and the applications so that the applications can be presented along with the theory, but that leads to other problems. Among other things, it would be time consuming and perhaps confusing and difficult for the students to differentiate between the curriculum and the extra-curricular content.

It is quite possible that a different presentation form would be better suited for explaining the relevance of logarithms. Different authors have proposed a wide array of different ways to connect school-, college- or university-mathematics with uses in other contexts. Mustoe and Croft (1999) proposes using case studies to enthuse students in school and college about engineering education; this approach may be fruitful if the audience is relatively homogenous on considering an engineering education, and similar case studies for other fields may be developed. Other writers have suggested mixing authentic problems into the teaching as examples (Flegg et. al., 2012; Coupland et. al., 2008) or inquiry-based modelling problems (Wedelin & Adawi, 2012). All of these methods have the same disadvantage that they cannot be broad enough to comply with the multivoicedness of a mathematics classroom in upper secondary school. However, all of these approaches can give the students an answer to the general justification problem: why is this particular aspect of mathematics taught at all? I content that one of the pitfalls that this kind of presentation can fall into (figure 32a) are partly caused by the fact that the video aims at providing a *satisfactory* answer to the justification question. Other methods, for example including authentic examples into the teaching, does not necessarily aim at conveying an answer that is satisfactory to all students. Thus, if a student does not find the particular example relevant, then that does not imply that the mathematical concept itself is not relevant to the student.

At least two other mediums has the potential to present the broadness. It is possible to present a similar material on a poster, similar to the "curriculum map" proposed by Kember et. al. (2008). In that case, it is not possible to include an audio narrative and animations. Advantages to this method includes that it is readily available, it is easy to make and adapt to different target groups, and it allows the viewers to focus selectively in the elements they are most interested in and find most relevant.

Another option is to present the material orally, possibly aided by a power point presentation. One major disadvantage to this method is that it requires a thorough preparation, but it allows the audience to ask questions while you talk and it is easy to adapt to different audiences.

The students commented on two technical issues. One student wanted the screencast to linger for a few moments on each graph after the audio narrative finished discussing it. This comment indicates that some form of cognitive overload has occurred, likely type 1 or type 2. The graphs contains written text, and the use of the cursor, zooming and movement makes the graphs 'animated'. Thus, type 1 overload may have occurred, which occurs because you need to focus on a visual animation and a printed text simultaneously. I did not foresee this problem because I did not think of the graphs as 'printed text' but 'pictures'. This can be solved, at least partially, by including a reading of the written text in the audio narrative (Mayer & Moreno, 2003). A type 2 overload, where both the visual and auditory channels are overloaded, is also likely to have occurred here. It is because the students need to focus on both a visual presentation, and an audio narrative. One possible solution is to give the students more pretraining in characteristics of the graphs, for example making the transition from logarithmic scale into logarithmic plot clearer. Nevertheless, because of the format, it is fully possible for the students to press 'pause' when they are watching the screencast, and take time to dwell on each graph.

The other technical commentary concerned the quality of the images: they are blurry. This is a big problem with my screencast, and it is possible to make a new video with higher quality. The reason I did not use a more professional equipment for the recording is that it would be too time consuming. Such equipment is available. Better production equipment would also allow me to show my face during the video, another one of the advice from Guo et. al. (2014).

Two students also commented that they did not recognize or remember some of the words used in the screencast, like 'real numbers' and 'the natural logarithm'. When I made the screencast, I assumed that the students were sufficiently familiar with these terms to understand the presentation, but for those students who found these terms difficult, it is possible that type 2 overload occurred, that essential processing of visual and auditory input overloaded both channels. A quick mention of the definition of these terms could solve the problem, for example a short commentary like "do you remember the natural logarithm? It is the logarithm base e, the Euler number". I think this explanation would be sufficient because they know the terms, but may not remember them correctly or sufficiently. Similarly, it would be possible to define the real numbers shortly, for example through a number line, before explaining that logarithms can be used to show that the cardinality of real numbers equals the cardinality of positive real numbers.

One of the students, Gjertrud, suggested that this kind of video could be used as an *introduction* to mathematical topics, instead of an ending, as I did. One reason I did not make the screencast into an introduction, is that the students that I interviewed, were finished with logarithms at the time that the interview needed to be conducted. However, adapting the material into an introduction may be a very good idea because if it is correct what the students say, that the video is motivating, then this motivation is good to have *before* they start to learn about the topic. That would require a different shape and content, because in its current shape, the screencast presupposes that the viewers already have knowledge of logarithms and know the meaning of the term 'natural logarithm'.

9.2.2 Improvement of the Interview

It is impossible to circumvent the effect I as the interviewer, and the interview setting itself, has on the subjects. Some of the interview objects were hesitant to talk once I turned on the microphone, and this effect can account for some of the hesitation and mumbling I encountered. This can also have a negative impact on their answers. Some of the interview objects gave rich and nuanced answers without encouragement whilst others were hesitant to answer simple questions and spoke in grammatically inconsistent sentences. Another possible effect stems from the group interview situation: not only can the recording equipment and I stress them. The presence of a peer can also affect them, for better or worse: it is possible that the other student makes them feel more at ease, relieving some of the stress of the interview setting. It may also have happened that some students withheld relevant information to avoid telling the other student. Maybe larger interview groups, for example three students at a time, would improve the results further, and individual interviews could be better in other cases.

Reviewing the results, there are many questions that I could have asked that would enrich the results. For example, some students explained that they have no concrete plans for further studies or career. However, do they plan to take higher education at all? A short follow up question could solve that problem. Another student, Hilde, indicated that the screencast could be working against its intention by deterring students that struggle with logarithms from pursuing studies and professions that involve logarithms, but her co-interview-object interrupted her from elaborating further. I should have asked more questions about this to get a more nuanced answer on this question. Another statement that I would like to get a better picture of is Christian's statements that the screencast failed to demonstrate uses of logarithms in day-to-day activities, and that he does not see himself making graphs when he arrives at work. Did he mean to imply that the screencast demonstrated that logarithms are not relevant to him? He did follow up by saying that the screencast demonstrated that logarithms have applications, but presumably not applications that are relevant for him. A simple follow-up question would make his comment much clearer. I assume that the screencast failed to demonstrate to him that logarithms are relevant to him personally, but that the general justification problem, "why do *we* need to learn about logarithms", was answered.

9.3 Conclusion

The research question for Study 2 was "what are students' views on screencast aiming to answer the question 'why do I need to learn about logarithms?'" In this section, I will summarize what findings I have that can enlighten this question.

The students interviewed were united on some aspects of the screencast, and divided on other aspects. All the students seemed to agree that it is good to learn about practical applications of logarithms, and that the screencast succeeded in demonstrating that there exists such applications. Some students found all or most of the examples mentioned relevant; many students were surprised to learn about the diversity and amount of the disciplines where logarithms are used; some students were enthusiastic to learn about new disciplines; and some did not find any of the examples in the screencast relevant to themselves.

One of my findings is that the students were divided on how much emphasis the video should have on mathematical technique versus the simplicity of the presentation, which confirms findings by Mustoe and Croft (1999) and Loch and Lamborn (2016). Compromising these two conflicting aims was also one of the biggest challenges with making the screencast.

Another finding is that this kind of video can be counter-productive. One student indicated that the screencast could be deterring her from pursuing an education or professions that involves logarithms, which confirms findings by Loch and Lamborn (2016). Another student indicated that the screencast did not demonstrate any forms of usefulness that he could connect with his objects or motivations. That can mean that the screencast implied to him that logarithms are not relevant to him. This confirms findings by Kember et. al. (2008).

10 Final Remarks and Didactical Implications

In the tenth chapter, I discuss the initial hypotheses in light of the findings (10.1), final remarks on the theoretical framework (10.2) and final remarks and didactical implications on my findings (10.3).

10.1 What do the Results say about the Hypotheses?

This research also builds on two hypotheses. In this section, I will discuss what I can say about them, based on the findings. The first hypothesis was that

1) Students in upper secondary school have little knowledge of how the mathematics they learn is useful outside school. This can have many causes. One is that teachers often have a university background with subject-specific teacher education. Such an education gives little weight to how one can use the content, and the teacher educators likely knows little about these themselves.

The students that I interviewed had indeed very little knowledge of the uses of logarithms. Only one student could come up with an example, and that was from another school subject, chemistry. This aligns with my first initial hypothesis. This finding aligns closely with Gebremichael's (2014) finding that chemistry students in university did not know anything about how the mathematics they were learning was relevant to their field, and perceived that their mathematics courses were not relevant to their field of study.

2) Information on the relevance of mathematics is something many students want, and it can be motivating. The students have made a choice to go to a university-preparatory programme, and even selected the most demanding mathematics course available. Therefore, I hypothesise that many of them have ambitions to study mathematics related topics at university of college level, and that this influences what kinds of uses that they will perceive as relevant.

All the students that I interviewed were very positive about learning more about the uses of the mathematics that they are learning. One of them even went as far as to say that the lack of such information is a "major problem" in school. I also found indicators that some of the students viewed the relevance of mathematics as mostly connected with mathematics as an assessment tool, assessing the student's suitability for particular studies and professions. This indicated that the school system and the system for admission into tertiary education, in addition to the lack of knowledge of the usefulness of mathematics, has mediated the student's perception of the relevance of mathematics. All the students that I interviewed agreed that it could be motivating to learn about the usefulness of mathematics, and this has been found and confirmed many times in the literature (Frymier & Schulman, 1995; Weaver & Cottrell, 1988; Sass, 1989, Keller 1983, 1987; Barnes, 1999; Kember, 2008). Their motives for choosing R1-mathematics can be grouped into two categories: those who want to study something related to mathematics, and those who are undecided and do not want to exclude any of the options that require or recommend R1 or R2 mathematics. Of the eight students interviewed, four students (André, Bjørn, Christian and Emilie) were relatively certain that they wanted to study something related to STEM. The other four students (Daniel, Fredrik, Gjertrud and Hilde) had not yet decided between fields related to mathematics and something different (Fredrik and Gjertrud), completely blank on this issue (Hilde), or the ambitions were connected with money and status (Daniel), and not a particular field or science. The number of participants is far too low for this result to be generalized to larger groups of students, but these findings clearly demonstrate how multivoiced a mathematics classroom is. At least one of the students clearly expressed that he would like a greater focus on the technical details of how logarithms are used and less focus on graphs in the video. This can indicate that he wanted or expected more emphasis on uses of logarithms within the disciplines that he expressed interest in, including building engineering and marine engineering. Overall, the results indicate that the second initial hypothesis is true.

10.2 Final Remarks on the Theoretical Framework

In the two studies that I conducted, I used Cultural-historical Activity Theory (ChAT) as a lens to look at my data. In ChAT, a distinction is made between an object of an activity and the tools that mediate the activity. ChAT proved helpful, for example, because it made me aware in Study 1 that logarithms were a tool in all kinds of research disciplines, even in mathematics. With logarithms being a tool in many areas, this makes logarithms relevant and so many students have to learn about them. However, with logarithms being a tool, it explains some of the tensions that we see in education, where logarithms are an object in itself, and not a tool.

In Study 2, ChAT allowed me to see students within different contexts and the tensions that can arise between these. The activity system of the school differs from future activity systems (university, future workplaces, family). It looks like schools tend to live in their "bubble", where teachers and textbooks make students do logarithms tasks, without showing a horizon on future activity systems. My study shows that there is room for improvement on assisting students to see how mathematics is used in professions.

10.3 Final Remarks and Didactical Implications

It is very possible for teacher to take action to make mathematics more relevant for students in upper secondary, and my results indicate that this is something the students want and that it can be motivating. The action can take many forms; the important thing is to make a connection between the topic and the students' goals. This requires knowledge of the students' goals, primarily goals for future education and profession, and knowledge of how the topic is applied in those educations and professions.

It is only the teacher that can obtain knowledge of students' goals, although some general, statistical trends can be inferred from various sources, like admission statistics and surveys of students' interests. But the task of finding examples of how, why and by whom the topics are applied, can equally well, perhaps better, be done by other people, for example researchers in mathematics education. My results indicate that the students in this group, students taking R1 in a public upper secondary school, have only vague goals for future education and profession. One reason for this may be that these students are in their first and second year of upper secondary education, and will therefore not apply for university of college education this year. For this reason, students in the third and last year of upper secondary education and therefore likely to have clearer goals. This implies that students taking mathematics courses in the first and second year of upper secondary education are likely to consider a broad range of possible future study programmes and professions, whereas students taking mathematics courses in the third and last year are likely to have goals that are more specific.

It remains open how and when this material should be presented. One option is to make presentations of the relevance of mathematics topics, as I did. This can be done in many ways, including screencasts, more advanced videos, posters and lectures, and the results indicate that it would be better to use this kind of material as an introduction, rather than an ending or conclusion of a topic. Another option is to use authentic examples in the exercises in the textbooks. An incentive for doing this can be to add weight to applications of mathematics in the curriculum, thereby forcing textbook writers and teachers to include examples that demonstrate that mathematics is useful. A third option is to use authentic case studies of scenarios where a particular mathematical concept is applied to solve a problem in engineering, economy, science etc. This will be time consuming, but can be incorporated with learning objectives from other subjects, and inquiry learning. My results indicates the in the absence of such example, the structure of the school system and system for admission to university and college education may mediate some of the students perception of the relevance of mathematics, to the point where mathematics is seen merely as a tool for measuring their competence and suitability for certain study programmes.

A similar method can be used to make presentations of the relevance of other topics within mathematics, and for other target groups. A larger study, comparing different presentation forms, different target groups or covering different concepts and topics, could provide cues to what presentation forms (video, poster or lecture), content (balance between 'too mathematically technical' and 'too simplistic') and strategies (presentation as introduction or conclusion to a mathematical concept?) are best suited and most efficient for the task of answering the question "why do I need to learn about this?" in mathematics.

11 Literature List

Allometry. (2014). Allometry. In M. Allaby (Ed.), *A Dictionary of Zoology*. Oxford: Oxford University Press.

Arlegi, M., Gómez-Olivencia, A., Albessard, L., Martínez, I., Balzeau, A., Arsuaga, J. L., & Been, E. (2017). The role of allometry and posture in the evolution of the hominin subaxial cervical spine. *Journal of Human Evolution, 104*, 80-99. doi:http://dx.doi.org/10.1016/j.jhevol.2017.01.002

Barnes, G. (1999). A motivational model of enrolment intentions in senior secondary science in New South Wales (Australia) schools. *Unpublished PhD thesis, University of Western Sydney, Sydney, NSW.*

Bassey, M. (1999). *Case study research in educational settings*. Buckingham: Open University Press.

Berg, J. M., Tymoczko, J. L., & Stryer, L. (2007). *Biochemistry* (6th ed.). New York: Freeman.

Boaler, J. (2008). *What's math got to do with it : helping children learn to love their most hated subject-and why it' s important for America*. New York: Viking.

Bogdan, R., & Biklen, S. K. (1992). *Qualitative research for education : an introduction to theory and methods* (2nd ed.). Boston: Allyn and Bacon.

Botten, G. (2009). *Meningsfylt matematikk: nærhet og engasjement i læringen* (3rd ed.). Bergen: Caspar Forlag.

Cariveau, D. P., Nayak, G. K., Bartomeus, I., Zientek, J., Ascher, J. S., Gibbs, J., & Winfree, R. (2016). The allometry of bee proboscis length and its uses in ecology. *PloS one, 11*(3), 1-13. doi: https://doi.org/10.1371/journal.pone.0151482

Centres for Disease Control and Prevention. (2012). Principles of Epidemiology in Public Health Practice, Third Edition An Introduction to Applied Epidemiology and Biostatistics. Retrieved May 9th 2017. Retrieved from https://www.cdc.gov/ophss/csels/dsepd/ss1978/lesson4/section3.html

Cheng, S. H., Higham, N. J., Kenney, C. S., & Laub, A. J. (2001). Approximating the logarithm of a matrix to specified accuracy. *SIAM Journal on Matrix Analysis and Applications, 22*(4), 1112-1125.

Clark, R. C., & Mayer, R. E. (2016). *E-learning and the science of instruction: Proven guidelines for consumers and designers of multimedia learning* (4th ed.): John Wiley & Sons.

Corbin, J. M., & Strauss, A. L. (2008). *Basics of qualitative research : techniques and procedures for developing grounded theory* (3rd ed.). Thousand Oaks, Calif: Sage.

Coupland, M., Gardner, A., & Carmody, G. (2008). *Mathematics for engineering education: what students say.* Paper presented at the Proceedings of the 31st Annual Conference of the Mathematics Education Research Group of Australasia.

Culver, W. J. (1966). On the existence and uniqueness of the real logarithm of a matrix. *Proceedings of the American Mathematical Society, 17*(5), 1146-1151.

Devore, J. L., & Berk, K. N. (2012). *Modern Mathematical Statistics with Applications*. New York, NY: Springer New York.

Donald, B., Xavier, P., Canny, J., & Reif, J. (1993). Kinodynamic motion planning. *Journal of the ACM (JACM), 40*(5), 1048-1066.

Engeström, Y. (2001). Expansive learning at work: Toward an activity theoretical reconceptualization. *Journal of education and work, 14*(1), 133-156.

Engeström, Y. (2015). *Learning by expanding : an activity-theoretical approach to developmental research* (2nd ed.). New York: Cambridge University Press.

Ernest, P. (2004). Relevance versus Utility: some ideas on what it means to know mathematics in society. In B. Clarke, E. National Center for Mathematics, & N. C. M. M. Conference (Eds.), *International Perspectives on Learning and Teaching Mathematics* (pp. 313-327). Göteborg: NCM.

Ernest, P. (2005). Platform: Why Teach Mathematics? *Mathematics in School, 34*(1), 28-29.

Fitts, P. M. (1954). The information capacity of the human motor system in controlling the amplitude of movement. *Journal of experimental psychology, 47*(6), 381-391.

Flegg, J., Mallet, D., & Lupton, M. (2012). Students' perceptions of the relevance of mathematics in engineering. *International Journal of Mathematical Education in Science and Technology, 43*(6), 717-732.

Franz, R., Hummel, J., Kienzle, E., Kölle, P., Gunga, H.-C., & Clauss, M. (2009). Allometry of visceral organs in living amniotes and its implications for sauropod dinosaurs. *Proceedings of the Royal Society of London B: Biological Sciences*, (pp. 1-6). doi: doi:10.1098/rspb.2008.1735

Freedman, R. A., Geller, R. M., & Kaufmann, W. J. (2011). *Universe* (9th ed.). New York: W.H. Freeman and Co.

Frymier, A. B., & Shulman, G. M. (1995). "What's in it for me?": Increasing content relevance to enhance students' motivation. *Communication Education, 44*(1), 40-50.

Gapminder. (n.d.-a). About Gapminder. Retrieved May 9th 2017. Retrieved from http://www.gapminder.org/about-gapminder/

Gapminder. (n.d.-b). Wealth and Health of Nations. Retrieved may 9th 2017. Retrieved from http://www.gapminder.org/tools/#_locale_id=en;&chart-type=bubbles

Gebremichael, A. T. (2014). *Why do chemistry students need to take mathematics courses?* Paper presented at the Frontiers in Mathematics and Science Education Research Conference, Famagusta, North Cyprus. Abstract retrieved from http://scimath.net/fiser2014/presentations/Andualem%20Tamiru%20Gebremichael_2.pdf

Gebremichael, A. T., Goodchild, S., & Nygaard, O. (2011). *Students perceptions about the relevance of mathematics in an Ethiopian preparatory school.* Paper presented at the The Seventh Congress of the European Society for Research in Mathematics Education, Rzeszow, Poland.

Giles, D. E. (2007). Benford's law and naturally occurring prices in certain ebaY auctions. *Applied Economics Letters, 14*(3), 157-161.

Gompertz, B. (1825). On the nature of the function expressive of the law of human mortality, and on a new mode of determining the value of life contingencies. *Philosophical transactions of the Royal Society of London, 115*, 513-583.

Goodchild, S. (2001). *Students' goals : a case study of activity in a mathematics classroom*. Bergen: Caspar forlag.

Gowers, T. (2008a). The Exponential and Logarithmic Functions. In T. Gowers, J. Barrow-Green, & I. Leader (Eds.), *The Princeton companion to mathematics* (pp. 199-202). Princeton, N.J: Princeton University Press.

Gowers, T. (2008b). The Prime Number Theorem and the Riemann Hypothesis. In T. Gowers, J. Barrow-Green, & I. Leader (Eds.), *The Princeton companion to mathematics* (pp. 714-715). Princeton, N.J: Princeton University Press.

Gowers, T., Barrow-Green, J., & Leader, I. (2008). *The Princeton companion to mathematics*. Princeton, N.J: Princeton University Press.

Grabiński, K., & Paszek, Z. (2013). Examining Reliability of Large Financial Datasets Using Benford's Law. *Ekonomiske Teme, 51*(3), 515-524.

Greene, W. H. (2012). *Econometric analysis* (7th ed.). Boston: Pearson.

Grillo, O. N., & Delcourt, R. (2017). Allometry and body length of abelisauroid theropods: Pycnonemosaurus nevesi is the new king. *Cretaceous Research, 69*, 71-89. doi:10.1016/j.cretres.2016.09.001

Grøn, Ø. (2015). *Termodynamikk for høgskole og universitet*. Oslo: Cappelen Damm akademisk.

Guo, P. J., Kim, J., & Rubin, R. (2014). *How video production affects student engagement: an empirical study of MOOC videos.* Paper presented at the L@S '14 Proceedings of the first ACM conference on Learning @ scale conference, Atlanta, Georgia, USA.

Heymann, H. W. (2003). *Why teach mathematics? : a focus on general education* (Vol. vol 33). Dordrecht: Kluwer Academic.

Hick, W. E. (1952). On the rate of gain of information. *Quarterly Journal of Experimental Psychology, 4*(1), 11-26.

Hill, C., Benhamou, E., & Doyon, F. (1991). Trends in cancer mortality, France 1950-1985. *British journal of cancer, 63*(4), 587-590.

Hill, T. P. (1998). The First Digit Phenomenon A century-old observation about an unexpected pattern in many numerical tables applies to the stock market, census statistics and accounting data. *American scientist, 86*(4), 358-363.

Hyman, R. (1953). Stimulus information as a determinant of reaction time. *Journal of experimental psychology, 45*(3), 188-196.

Interesting. (n.d.). Oxford Dictionaries. Retrieved may 9th 2017. Retrieved from https://en.oxforddictionaries.com/definition/interesting

Jacobsen, D. I. (2005). *Hvordan gjennomføre undersøkelser? : innføring i samfunnsvitenskapelig metode* (2nd ed.). Kristiansand: Høyskoleforlaget

Jacques, I. (2006). *Mathematics for economics and business* (5th ed.). Harlow: Pearson Education.

Johnson, G. G., & Weggenmann, J. (2013). Exploratory Research Applying Benford's Law to Selected Balances in the Financial Statements of State Governments. *Academy of Accounting and Financial Studies Journal, 17*(3), 31-44.

Judge, G., & Schechter, L. (2009). Detecting problems in survey data using Benford’s Law. *Journal of Human Resources, 44*(1), 1-24.

Julie, C., & Mbekwa, M. (2005). What would Grade 8 to 10 learners prefer as context for mathematical literacy? The case of Masilakele Secondary School: research article: mathematics and science education. *Perspectives in Education, 23*(1), 31-43.

Kacerja, S. (2012). *Real-life contexts in mathematics and students' interests : an Albanian study*. Unpilished PhD Thesis, University of Agder, Faculty of Engineering and Science, Kristiansand.

Katz, V. J. (2004). *The history of mathematics : brief version*. Boston: Pearson/Addison-Wesley.

Keller, J. M. (1983). Motivational design of instruction. In C. M. Reigeluth (Ed.), *Instructional design theories and models: An overview of their current status* (Vol. 1, pp. 383-434). New Jersey: Hillsdale.

Keller, J. M. (1987). Development and use of the ARCS model of motivational design. *Journal of Instructional Development, 10*(3), 2–10.

Kember, D., Ho, A., & Hong, C. (2008). The importance of establishing relevance in motivating student learning. *Active learning in higher education, 9*(3), 249–263.

Kumar, R. (2016). Analysis of the pH-dependent thermodynamic stability, local motions, and microsecond folding kinetics of carbonmonoxycytochrome c. *Archives of Biochemistry and Biophysics, 606*, 16-25. doi:http://dx.doi.org/10.1016/j.abb.2016.07.010

Kvale, S., & Brinkmann, S. (2015). *Det kvalitative forskningsintervju* (3rd ed.). Oslo: Gyldendal akademisk.
Kämpf, K., Klameth, F., & Vogel, M. (2012). Power-law and logarithmic relaxations of hydrated proteins: A molecular dynamics simulations study. *The Journal of chemical physics, 137*(20), 205105-205113. doi: 10.1063/1.4768046
Larsen, R. J., & Marx, M. L. (2012). *An Introduction to Mathematical Statistics and Its Applications. International edition. Fifth edition.* (5th ed.). Boston, MA: Pearson.
Laumond, J.-P., Benallegue, M., Carpentier, J., & Berthoz, A. (2016). The yoyo-man. *The International Journal of Robotics Research*. doi:10.1177/0278364917693292
Leemis, L. M., Schmeiser, B. W., & Evans, D. L. (2000). Survival Distributions Satisfying Benford's Law. *The American Statistician, 54*(4), 236-241. doi:10.1080/00031305.2000.10474554
Li, L., Zou, C., Zhou, L., & Lin, L. (2017). Cucurbituril-protected Cs2.5H0.5PW12O40 for optimized biodiesel production from waste cooking oil. *Renewable Energy, 107*, 14-22. doi:http://dx.doi.org/10.1016/j.renene.2017.01.053
Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Beverly Hills, Calif: Sage.
Loch, B., & Lamborn, J. (2016). How to Make Mathematics Relevant to First-Year Engineering Students: Perceptions of Students on Student-Produced Resources. *International Journal of Mathematical Education in Science and Technology, 47*(1), 29-44. doi:10.1080/0020739X.2015.1044043
Longstreth, L. E., El-Zahhar, N., & Alcorn, M. B. (1985). Exceptions to Hick's law: Explorations with a response duration measure. *Journal of Experimental Psychology: General, 114*(4), 417-434. doi: https://doi.org/10.1016/j.geothermics.2015.01.010
Ma, Y., Wang, Q., Sun, X., Wu, C., & Gao, Z. (2017). Kinetics studies of biodiesel production from waste cooking oil using FeCl3-modified resin as heterogeneous catalyst. *Renewable Energy, 107*, 522-530. doi:http://dx.doi.org/10.1016/j.renene.2017.02.007
Maas, I., & van Leeuwen, M. H. D. (2016). Toward Open Societies? Trends in Male Intergenerational Class Mobility in European Countries during Industrialization. *American Journal of Sociology, 122*(3), 838-885. doi:10.1086/689815
Makeham, W. M. (1860). On the law of mortality and construction of annuity tables. *The Assurance Magazine and Journal of the Institute of Actuaries, 8*(6), 301-310.
Mayer, R. E., & Moreno, R. (2003). Nine Ways to Reduce Cognitive Load in Multimedia Learning. *Educational Psychologist, 38*(1), 43-52. doi:10.1207/S15326985EP3801_6
McLean, K., & Zarrouk, S. J. (2015). Geothermal well test analysis using the pressure derivative: Some common issues and solutions. *Geothermics, 55*, 108-125.
Meng, X., Zheng, D., Wang, J., & Li, X. (2013). Energy saving mechanism analysis of the absorption–compression hybrid refrigeration cycle. *Renewable Energy, 57*, 43-50. doi:http://dx.doi.org/10.1016/j.renene.2013.01.008
Mertens, D. M. (2014). *Research and evaluation in education and psychology : integrating diversity with quantiative, qualitative and mixed methods* (4th ed.). Los Angeles: SAGE.
Munroe, R. (2012). Forgot Algebra. Retrieved May 9th 2017. Retrieved from https://xkcd.com/1050/
Mustoe, L. R., & Croft, A. C. (1999). Motivating Engineering Students by Using Modern Case Studies. *International Journal of Engineering Education, 1999*(6), 469-476.
Oldervoll, T., Orskaug, O., Vaaje, A., Hanisch, F., & Hals, S. (2007). *Sinus R1 : grunnbok i matematikk : studiespesialiserende program*. Oslo: Cappelen.

Otte, M., & Frazzoli, E. (2015). RRT^{X}: Real-Time Motion Planning/Replanning for Environments with Unpredictable Obstacles. In H. L. Akin, N. M. Amato, V. Isler, & A. F. van der Stappen (Eds.), *Algorithmic Foundations of Robotics XI: Selected Contributions of the Eleventh International Workshop on the Algorithmic Foundations of Robotics* (pp. 461-478). Cham: Springer International Publishing.

Pemberton, M., & Rau, N. (2013). *Mathematics for economists : an introductory textbook* (3rd ed.). Manchester: Manchester University Press.

Pham, Q.-C., Caron, S., Lertkultanon, P., & Nakamura, Y. (2016). Admissible velocity propagation: Beyond quasi-static path planning for high-dimensional robots. *The International Journal of Robotics Research*, 36(1), 44-67. doi:10.1177/0278364916675419.

Price, E., & Woodruff, D. P. (2012). *Applications of the Shannon-Hartley theorem to data streams and sparse recovery*. Paper presented at the Information Theory Proceedings (ISIT), 2012 IEEE International Symposium on.

Salemi, M. K. (2013). Intermediate Macroeconomic Theory. In W. Page (Ed.), *Applications of mathematics in economics* (pp. 27-44). Washington, DC: Washington, DC: Mathematical Association of America.

Sambridge, M., Tkalčić, H., & Jackson, A. (2010). Benford's law in the natural sciences. *Geophysical research letters, 37*(22) 1-5. doi:10.1029/2010GL044830

Samordna Opptak. (2013). Realfagspoeng. Retrieved May 9th 2017. Retrieved from https://www.samordnaopptak.no/info/opptak/poengberegning/legge-til-poeng/realfagspoeng/

Sass, E. J. (1989). Motivation in the college classroom: What students tell us. *Teaching of psychology, 16*(2), 86-88.

Schoenfeld, A. H. (2016). *An Introduction to the Teaching for Robust Understanding (TRU) Framework*. Graduate School of Education. Berkeley, CA. Retrieved May 9th 2017. Retrieved from http://map.mathshell.org/trumath/intro_to_tru_20161223.pdf

Schreiner, C., & Sjøberg, S. (2004). ROSE: The relevance of science education. Sowing the seeds of ROSE. Background, Rationale, Questionnaire Development and Data Collection for ROSE (The Relevance of Science Education)–a comparative study of students' views of science and science education. *Acta didactica, 4*, 2004.

Schreiner, C., & Sjøberg, S. (2010). The ROSE project: An overview and key findings. *Oslo: University of Oslo*, 1-31.

Schwandt, T. A. (2000). Three Epistemological Stances for Qualitative Inquiry: Interpretivism, Hermeneutics, and Social Constructivism. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (2nd ed., pp. 189-213). Thousand Oaks, Calif: Sage.

Siegler, R. S., & Booth, J. L. (2004). Development of Numerical Estimation in Young Children. *Child Development, 75*(2), 428-444. doi:10.1111/j.1467-8624.2004.00684.x

Skovsmose, O. (2005). Foregrounds and politics of learning obstacles. *For the learning of mathematics, 25*(1), 4-10.

Smångs, M. (2016). Doing Violence, Making Race: Southern Lynching and White Racial Group Formation 1. *American Journal of Sociology, 121*(5), 1329-1374.

Sommervoll, D. E. (2016). *Matematikk for økonomifag* (3rd ed.). Oslo: Gyldendal akademisk.

Spelke, E. S., Dehaene, S., Izard, V., & Pica, P. (2008). Log or Linear? Distinct Intuitions of the Number Scale in Western and Amazonian Indigene Cultures. doi:10.1126/science.1156540

Stake, R. E. (2000). Case Studies. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (2nd ed., pp. 435-454). Thousand Oaks, Calif: Sage.

Statistisk sentralbyrå. (2017). Studenter i høyere utdanning. Retrieved May 9th 2017. Retrieved from https://www.ssb.no/utdanning/statistikker/utuvh

Stellwagen, N. C. (2017). Electrophoretic Mobilities of the Charge Variants of DNA and Other Polyelectrolytes: Similarities, Differences and Comparison With Theory. *The Journal of Physical Chemistry B*. 121(9), 2015-2026. doi: 10.1021/acs.jpcb.6b10599

Sugar, W., Brown, A., & Luterbach, K. (2010). Examining the anatomy of a screencast: Uncovering common elements and instructional strategies. *The International Review of Research in Open and Distributed Learning, 11*(3), 1-20.

Tušan, R. (2016). Using Benford's Law to the Detection of Misrepresentation of Financial Statements Data. *Annals of the University of Oradea, Economic Science Series, 25*(1), 737-745.

Utdanningsdirektoratet. (2013a). *Competence aims after 1T - Vg1 education programmes for general studies*. Retrieved May 9th 2017. Retrieved from https://www.udir.no/kl06/MAT1-04/Hele/Kompetansemaal/competence-aims-after-1t---vg1-education-programmes-for-general-studies?lplang=eng.

Utdanningsdirektoratet. (2013b). *Elever som tar fag fra videregående opplæring på ungdomstrinnet*. Retrieved May 9th 2017. Retrieved from https://www.udir.no/regelverk-og-tilsyn/finn-regelverk/etter-tema/Innhold-i-opplaringen/Udir-04-2013/.

Utdanningsdirektoratet. (2013c). *Mathematics for the Natural Sciences - Programme Subject for Specialization in General Studies*. Retrieved May 9th 2017. Retrieved from https://www.udir.no/kl06/MAT3-01/Hele/Kompetansemaal/mathematics-r1?lplang=eng.

Vos, P., & Espedal, B. (2016). Logarithms - a meaningful approach with repeated division. *Mathematics Teaching, 251*, 30-33.

Watts, G. (2009). Hans Rosling: Animated about statistics. *BMJ: British Medical Journal (Online), 339* 199-200. doi:10.1136/bmj.b2801

Weaver, R. L., & Cottrell, H. W. (1988). Motivating students: Stimulating and sustaining student effort. *College Student Journal*. 22(1) 22-32

Weber, C. (2016). Making Logarithms Accessible–Operational and Structural Basic Models for Logarithms. *Journal für Mathematik-Didaktik, 37*(1), 69-98. doi:10.1007/s13138-016-0104-6

Wedege, T. (2009). Needs versus Demands: Some ideas on what it means to know mathematics in society. In B. Sriraman & S. Goodchild (Eds.), *Relatively and philosophically Earnest: Festschrift in honor of Paul Ernest's 65th Birthday* (pp. 221-234). Charlotte, NC: Information Age Publishing.

Wedelin, D., & Adawi, T. (2014). Teaching Mathematical Modelling and Problem Solving-A Cognitive Apprenticeship Approach to Mathematics and Engineering Education. *iJEP, 4*(5), 49-55. doi: http://dx.doi.org/10.3991/ijep.v4i5.3555

Weisstein, E. W. (n.d.). Benford's Law. Retrieved May 9th 2017. Retrieved from http://mathworld.wolfram.com/BenfordsLaw.html

Wellington, J. (2015). *Educational research: Contemporary issues and practical approaches* (2nd ed.): Bloomsbury Publishing.

Wolfram, S. (2002). *A new kind of science*. Champaign, Il: Wolfram Media.

Wooldridge, J. M. (2010). *Econometric analysis of cross section and panel data* (2nd ed.). Cambridge, Mass: MIT Press.

Yin, R. K. (2014). *Case study research : design and methods* (5th ed.). Los Angeles, Calif: SAGE.

12 Appendices

12.1 Project Proposal by Pauline Vos

Pupil's knowledge of the relevance of mathematics

Project proposal for a possible Master's Thesis

September 2016

Supervisor: Professor Pauline Vos (contact: Pauline.vos@uia.no)

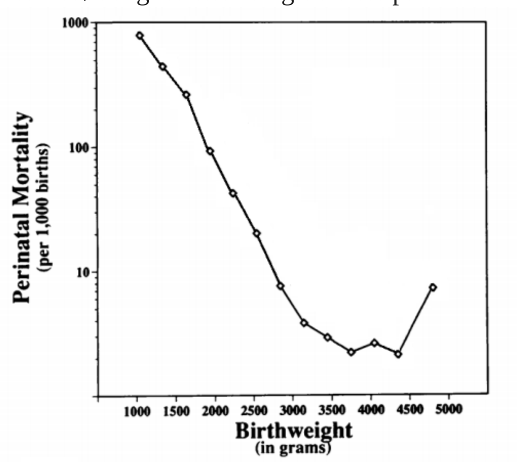
With this study, we want to assist pupils to answer the question *"why do we need to learn this?"* This study is part of a larger study on motivation and pupil's knowledge of the social relevance of mathematics.

I am looking for Master's students, who will do research on the *relevance of logarithms*, see the text below. Some lesson materials are available, but you may want to adapt these. The research will involve using the materials with pupils (you can decide which ones) and evaluating what they think of it (interviewing). The background literature pertains to *motivation* and *usefulness.*

(For our English-speaking students: the text below explains that logarithms are no longer needed for doing lengthy calculations. Instead logarithms are now needed in all areas where small and large numbers are used at the same time, for example in the medical sector. Below is a graph from an authentic medical publication on infant mortality after a pregnancy of nine months. Most babies with a small birth weight die; only few babies with a good birth weight die. To accommodate both "most" and "a few" into one graph, a logarithmic scale is used.)

Logaritmer er et viktig emne innen matematikk. Siden 1600-tallet har logaritmer vært til stor hjelp ved å forenkle ellers tidkrevende kalkulasjoner. Logaritmen til et tall kunne man finne i logaritmetabeller, som igjen ga regning med enklere operasjoner. I stedet for multiplikasjon og divisjon, kunne man addere og subtrahere. Regning med potenser og røtter ble redusert til multiplikasjon og divisjon.

Kalkulatorens ankomst endret betydningen av logaritmer. De er ikke lenger nødvendig i tidkrevende beregninger. I dag de er nyttige på områder der folk arbeider med målinger som har store spenn mellom høyeste til laveste verdi. I astronomi, for eksempel, vises avstander ofte logaritmisk. Ellers ville avstanden fra jorden til månen være for liten hvis den skulle brukes i sammenlikning med avstanden fra jorden til sorte hull, som er lysår unna. I måling av lyd bør må bruke en skala som kan ta hensyn til alle typer lydstyrker, alt fra lyden av et vindpust til lyden av en kraftig eksplosjon. Derfor brukes desibelskalaen (dB) som er logaritmisk. I helsesektoren ser vi også ofte logaritmer. For eksempel er dødelighet angitt som et forhold: x ut av tusen personer. Figur 1 viser en graf fra en autentisk akademisk medisinsk publisering på spedbarnsdødelighet etter en graviditet på ni måneder fødselsvekt (Wilcox, 1992). Fødselsvekt er uavhengig variabel. De fleste babyer med en liten fødselsvekt dør, mens bare noen få babyer med en normal fødselsvekt dør. For å imøtekomme både "de fleste" og "noen få" i en graf, er en logaritmisk skala er brukt. Dersom en normal (lineær) skala hadde blitt anvendt i en grafisk fremstilling av samme størrelser, ville lesbarheten forringes. Man kunne enten fokusere på den høyere dødeligheten ved lav fødselsvekt og dermed miste oppløsningen i dødelighet blant dem høy fødselsvekt. Alternativt kunne man fokusere på den lave dødeligheten blant dem med høy fødselsvekt og minste detaljer blant dem med lav fødselsvekt. En logaritmisk skala er hensiktsmessig for å tilfredsstille begge ønsker. Selv elever i ungdomsskolen kan arbeide med denne type skalaer.



Weight-specific mortality rates

Logaritmer blir altså brukt i skalering av denne type målinger, spesielt grafisk.

12.2 NSD Approval Form

NSD

Francisca Pauline Vos
Institutt for matematiske fag Universitetet i Agder
Serviceboks 422
4604 KRISTIANSAND S

Vår dato: 19.01.2017 Vår ref: 51582 / 3 / STM Deres dato: Deres ref:

TILBAKEMELDING PÅ MELDING OM BEHANDLING AV PERSONOPPLYSNINGER

Vi viser til melding om behandling av personopplysninger, mottatt 14.12.2016. Meldingen gjelder prosjektet:

51582	*Relevance of Logarithms*
Behandlingsansvarlig	*Universitetet i Agder, ved institusjonens øverste leder*
Daglig ansvarlig	*Francisca Pauline Vos*
Student	*Anders Wiik*

Personvernombudet har vurdert prosjektet og finner at behandlingen av personopplysninger er meldepliktig i henhold til personopplysningsloven § 31. Behandlingen tilfredsstiller kravene i personopplysningsloven.

Personvernombudets vurdering forutsetter at prosjektet gjennomføres i tråd med opplysningene gitt i meldeskjemaet, korrespondanse med ombudet, ombudets kommentarer samt personopplysningsloven og helseregisterloven med forskrifter. Behandlingen av personopplysninger kan settes i gang.

Det gjøres oppmerksom på at det skal gis ny melding dersom behandlingen endres i forhold til de opplysninger som ligger til grunn for personvernombudets vurdering. Endringsmeldinger gis via et eget skjema, http://www.nsd.uib.no/personvern/meldeplikt/skjema.html. Det skal også gis melding etter tre år dersom prosjektet fortsatt pågår. Meldinger skal skje skriftlig til ombudet.

Personvernombudet har lagt ut opplysninger om prosjektet i en offentlig database, http://pvo.nsd.no/prosjekt.

Personvernombudet vil ved prosjektets avslutning, 31.05.2017, rette en henvendelse angående status for behandlingen av personopplysninger.

Vennlig hilsen

Kjersti Haugstvedt

Siri Tenden Myklebust

Kontaktperson: Siri Tenden Myklebust tlf: 55 58 22 68
Vedlegg: Prosjektvurdering

Dokumentet er elektronisk produsert og godkjent ved NSDs rutiner for elektronisk godkjenning.

NSD – Norsk senter for forskningsdata AS Harald Hårfagres gate 29 Tel: +47-55 58 21 17 nsd@nsd.no Org.nr. 985 321 884
NSD – Norwegian Centre for Research Data NO-5007 Bergen, NORWAY Faks: +47-55 58 96 50 www.nsd.no

Personvernombudet for forskning

Prosjektvurdering - Kommentar

Prosjektnr: 51582

Personvernombudet legger til grunn at gjennomføringen av prosjektet er klarert med skolens ledelse.

Utvalget informeres skriftlig og muntlig om prosjektet og samtykker til deltakelse. Foresatte samtykker for unge under 18 år. Informasjonsskrivet er godt utformet.

I meldeskjemaet er det krysset av for at personopplysninger skal samles inn ved bruk av papirbasert spørreskjema, personlig intervju, gruppeintervju, observasjon og deltakende observasjon. Vi minner om at ved bruk av lydopptak i klasserommet, må alle som er til stede samtykke til deltakelse. Dersom enkelte av elevene ikke ønsker å delta, bør det tilrettelegges for et alternativt opplegg for disse. For eksempel at de deltar i undervisning med parallellklassen.

Personvernombudet legger til grunn at student etterfølger Universitetet i Agder sine interne rutiner for datasikkerhet.

Forventet prosjektslutt er 31.05.2017. Ifølge prosjektmeldingen skal innsamlede opplysninger da anonymiseres. Anonymisering innebærer å bearbeide datamaterialet slik at ingen enkeltpersoner kan gjenkjennes. Det gjøres ved å:
- slette direkte personopplysninger (som navn/koblingsnøkkel)
- slette/omskrive indirekte personopplysninger (identifiserende sammenstilling av bakgrunnsopplysninger som f.eks. bosted/skole, alder og kjønn)
- slette digitale lydopptak

12.3 Information Form

Forespørsel om deltakelse i forskningsprosjektet

Relevansen av logaritmer

Bakgrunn og formål

Studien er en masteroppgave og utføres under master i matematikkdidaktikk på Universitetet i Agder. Formålet er å undersøke om elever opplever undervisningen som relevant, spesifikt om det er relevant å lære om logaritmer. Problemstillingen vil handle om dette. Det er ikke en ekstern oppdragsgiver og det gjennomføres ikke i samarbeid med andre institusjoner.

Elevgruppen er valgt på grunn av at de har hatt relevant matematikkundervisning og er tilgjengelige og villige til å delta i undersøkelsen.

Hva innebærer deltakelse i studien?

Deltakelsen i denne studien innebærer at elevene svarer på en undersøkelse, deltar i en presentasjon og eventuelt deltar i et intervju i etterkant. Elevene vil bli observert underveis. Opplegget forventes å vare 1-2 skoletimer.

Spørsmålene vil omhandle hva elevene tenker og mener er relevant med trigonometriske funksjoner.

Dersom foreldre samtykker for barn, vil de på forespørsel få tilgang på spørreskjema og intervjuguide.

Hva skjer med informasjonen om deg?

Alle personopplysninger vil bli behandlet konfidensielt. All informasjon som registreres underveis er kun tilgjengelig for jeg som masterstudent. Hvis det dukker opp sensitiv eller identifiserende vil dette ikke offentliggjøres. Og all data anonymiseres.

Alle lydopptak og observasjonsnotater lagres passordbeskyttet på Universitetet i Agder sin server.

Deltakere vil ikke kunne gjenkjennes i publikasjon.

Prosjektet skal etter planen avsluttes 31. Mai 2017. Senest 31. Mai blir alle lydopptakene slettet.

Frivillig deltakelse
Det er frivillig å delta i studien, og du kan når som helst trekke ditt samtykke uten å oppgi noen grunn. Dersom du trekker deg, vil alle opplysninger om deg bli anonymisert.

Dersom du ønsker å delta eller har spørsmål til studien, ta kontakt med prosjektleder Anders Wiik på 91384485, eller veileder Pauline Vos på 381 42 332.

Studien er meldt til Personvernombudet for forskning, NSD - Norsk senter for forskningsdata AS.

Samtykke til deltakelse i studien

Jeg har mottatt informasjon om studien, og er villig til å delta

----

(Signert av prosjektdeltaker, dato)

12.4 Standard email

Standard e-mail
Hei …

Jeg holder for tiden på med hovedoppgave om relevansen av logaritmer, og er interessert i å høre om hva mennesker i ulike matematikk-relaterte yrker tenker om dette. Om du har tid til å gi meg et svar, så ville det vært topp.

Spørsmålet er: **hva er relevansen av logaritmer for deg?**
Det kan være anvendelser i fagene dine, men også helt andre ting som faller deg inn.

I ditt tilfelle er jeg spesielt interessert i
-(skriv ned anvendelsesområder som er spesielt interessante)
-andre anvendelser?

Anvendelser som er lette å presentere visuelt, som er spesielt betydningsfulle, eller kan gi "aha"-opplevelser, er særlig verdifulle.

Responsen vil være en del av grunnlaget for å besvare spørsmålet "How can the question "why do I need to learn about logarithms" be answered?", og inngår i en større studie om relevansen av matematikk. Resultatene kan også anvendes i et dokument som skal presenteres for elever i videregående skole for å undersøke hvordan elevene forholder seg til dette. Er elevene opptatt av anvendelser av matematikken?

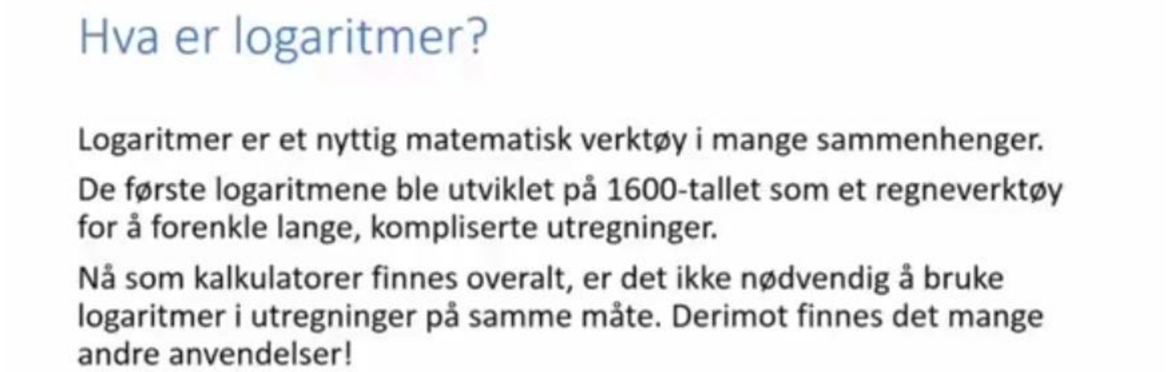
Det kan være interessant å høre andre … svare på det samme spørsmålet, både studenter, yrkesutøvere og akademikere (og andre?). Kjenner du noen som du tror vil være interessert i å gi sine svar, sett dem gjerne i kontakt med meg.

Takk for at du tar deg tid til dette, hilsen Anders Wiik
+47 91384485, anders.wiik.oskoreii (at) gmail.com

Hello,
I'm currently writing a master thesis on the relevance of logarithms, and I'm interested in hearing what people in different mathematics-related professions are thinking about this. If you've got time to reply, I would greatly appreciate it.
The question is: **what is the relevance of logarithms for you?**
It can be applications in your field of expertise, but also entirely different things coming to your mind.
With you, I'm particularly interested in
-[write down areas of particular interest, adapted to the field and recipient]
-Other applications?
Applications that can easily be presented visually, that have a particular significance, or can provide a "wow"-effect, are particularly interesting.
Your response will contribute in answering the research question " How can the question "why do I need to learn about logarithms" be answered?", and is part of a larger study about the relevance of mathematics. The results can also be used in a document that will be presented for pupils in upper secondary school, to investigate how they relate to the material. Are pupils concerned with applications of mathematics?
It may also be interesting to hear other… answer the same question, both students, non-academic professionals and academics. And others? If you know anyone that you think is willing to provide further information, you may give them my contact information
Thank you for your time and contribution,
Regards, Anders Wiik
+47 91384485, anders.wiik.oskoreii (at) gmail.com

12.5 Screenshots from the Screencast

Opening page, at 00:00. This is a short presentation of the screencast, together with an audio narrative that explains the aim of the screencast. The video can be found here: https://www.youtube.com/watch?v=nWQubl3D_1g



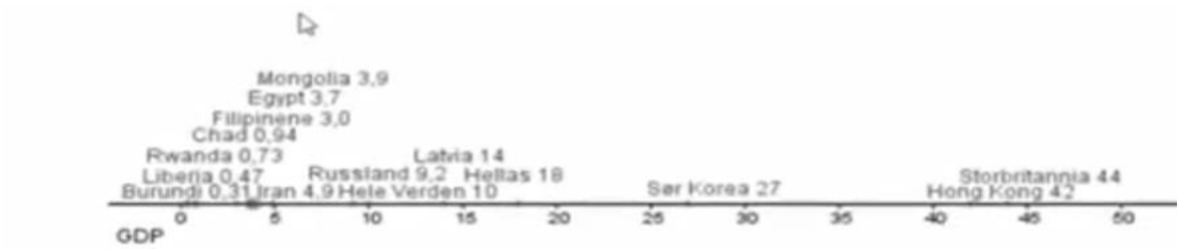
Introduction, at 00:17. This part contains a brief presentation of the historical role of logarithms.

Den viktigste bruken av logaritmer i dag er for presentasjon av tallmaterialer, der det er viktig å få frem hvordan tallmaterialet varierer i *størrelsesordener.*

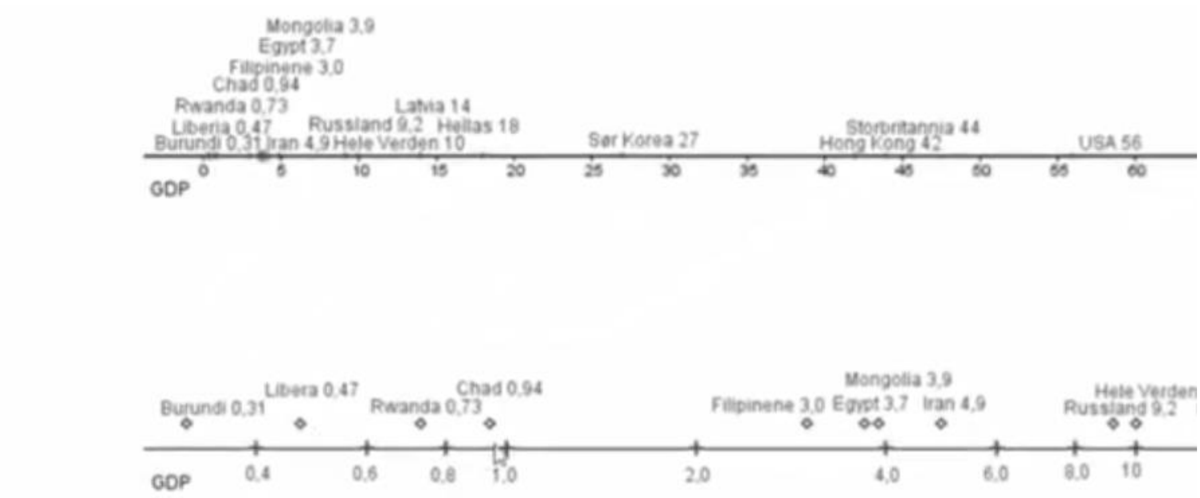
Se for deg at du skal lage en tallinje over økonomien til noen ulike land:

Land (høyt rangerte)	Brutto nasjonalprodukt per innbygger (2015, tusen US$)	Land (lavt rangerte)	Brutto nasjonalprodukt per innbygger (2015, tusen US$)
Luxembourg	102	Russland	9,2
Norge	75	Iran	4,9
USA	56	Mongolia	3,9
Storbritannia	44	Egypt	3,7
Hong Kong	42	Filipinene	3,0
Sør-Korea	27	Chad	0,94
Hellas	18	Rwanda	0,73
Latvia	14	Liberia	0,47
Hele verden	10	Burundi	0,31

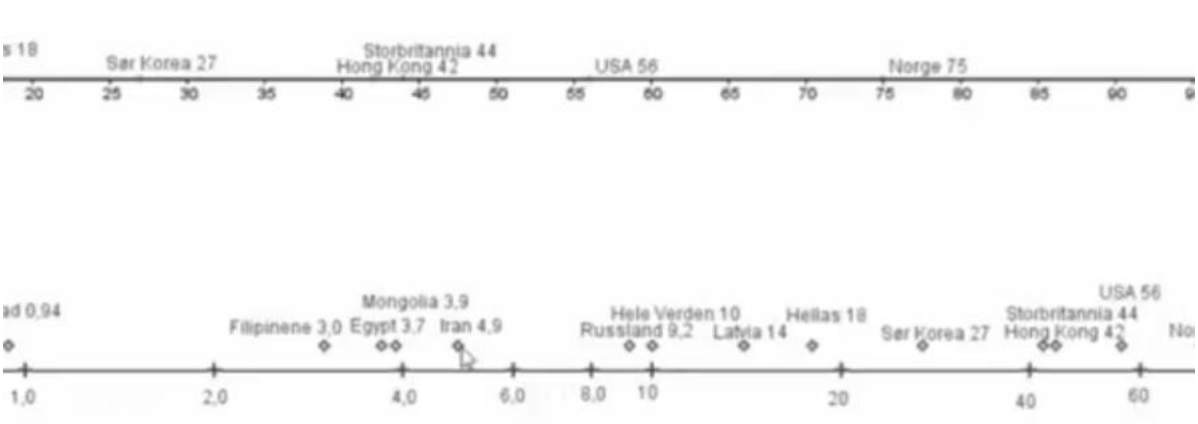
Second part, at 00:40. Here, a list on numbers on nominal gross domestic product is presented, along with a statement that logarithms are useful for presenting numbers that differ by orders of magnitude.



00:50, the third part where the same numbers are presented on a linear number line. The cursor is used to help the students focus on the part of the graph that is being discussed. The image is zoomed in on the lower part of the number line.



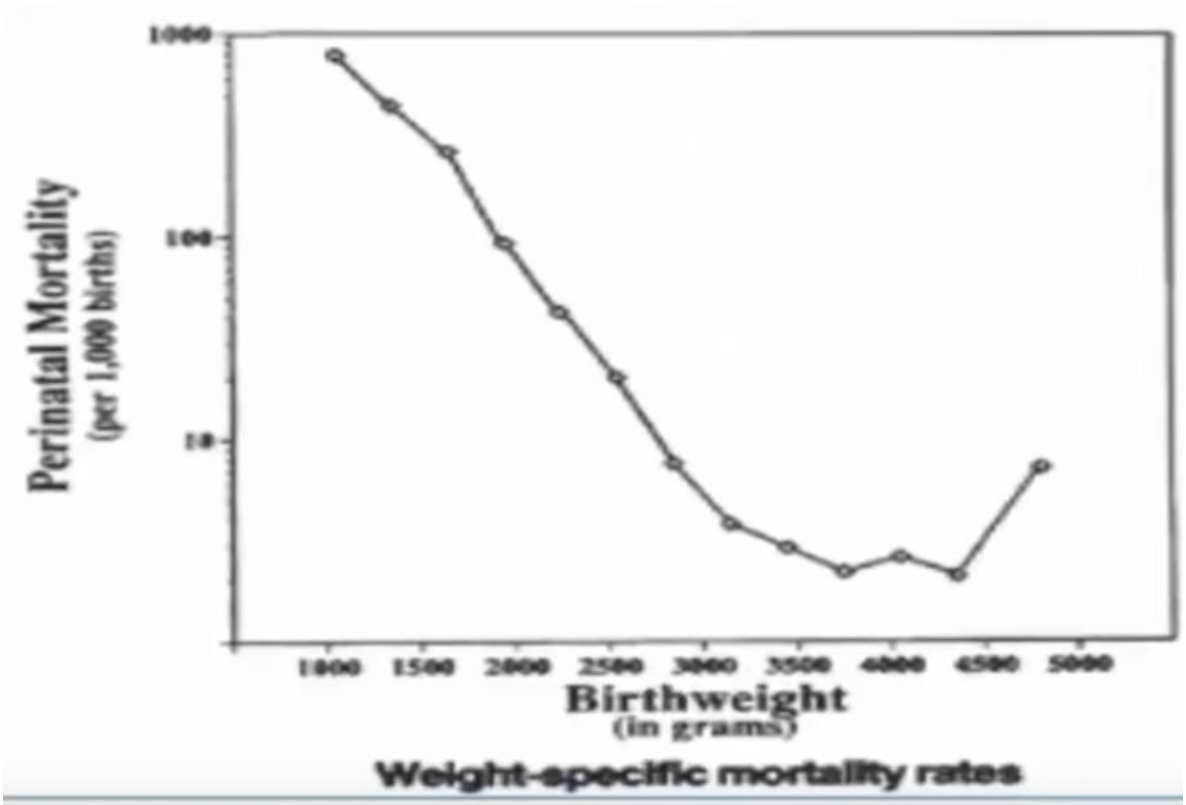
At 1:17, the above number line is contrasted with the same numbers on a logarithmic scale, to demonstrate how the cluster above is now evenly spread out.



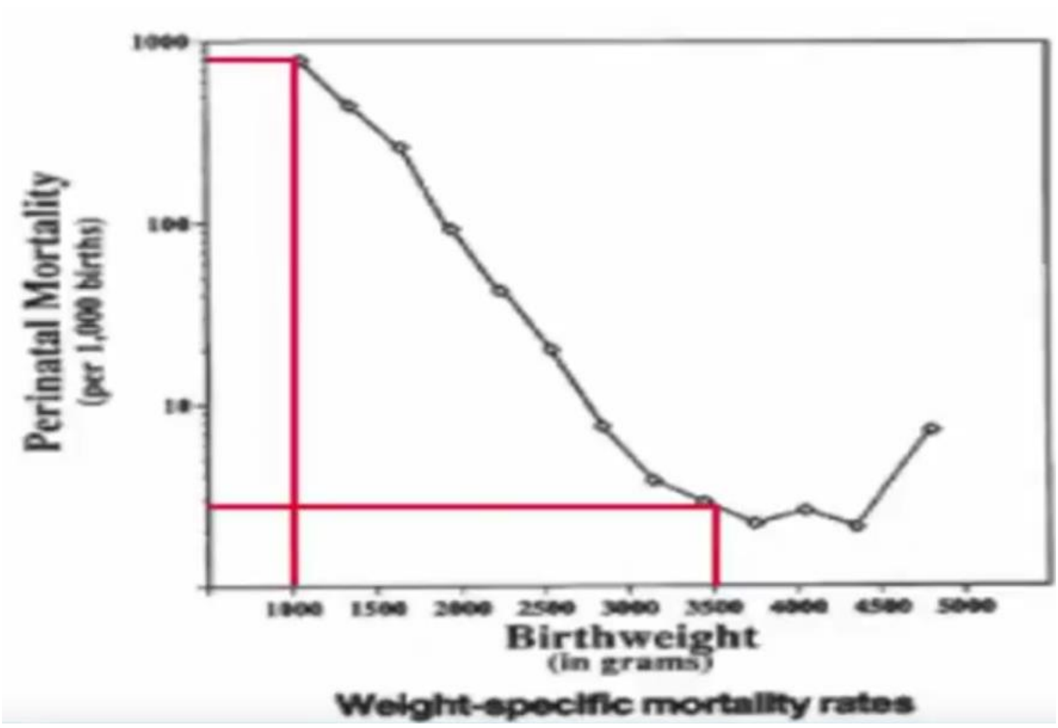
01:26, the focus is drawn to the left

01:38, fourth part, the first semi-logarithmic plot is introduced.

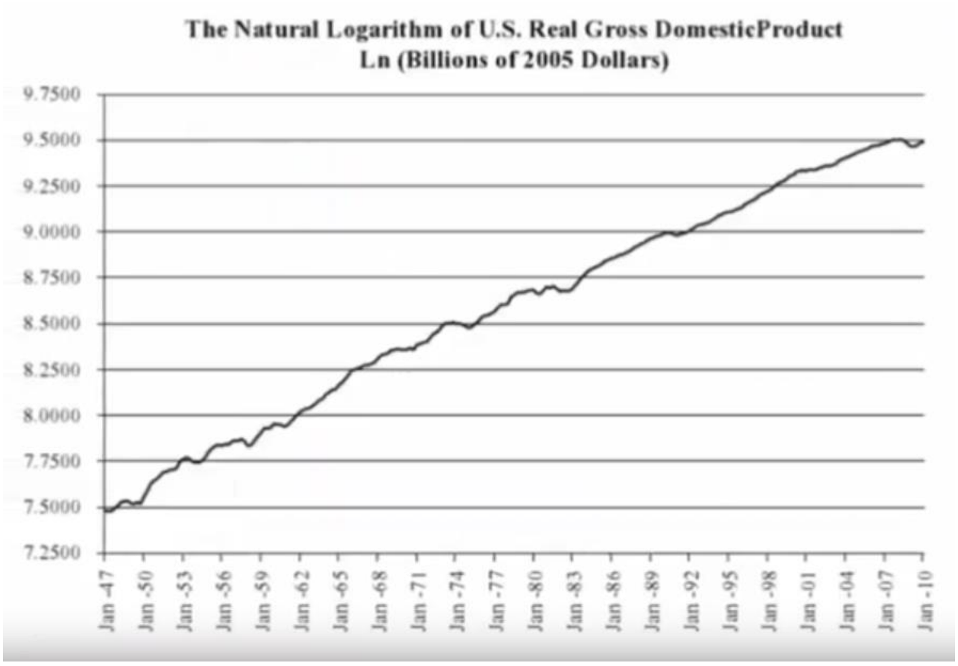
01:49, the focus is zoomed in and the cursor indicated to the student watching what part of the screen the audio narrative discusses.



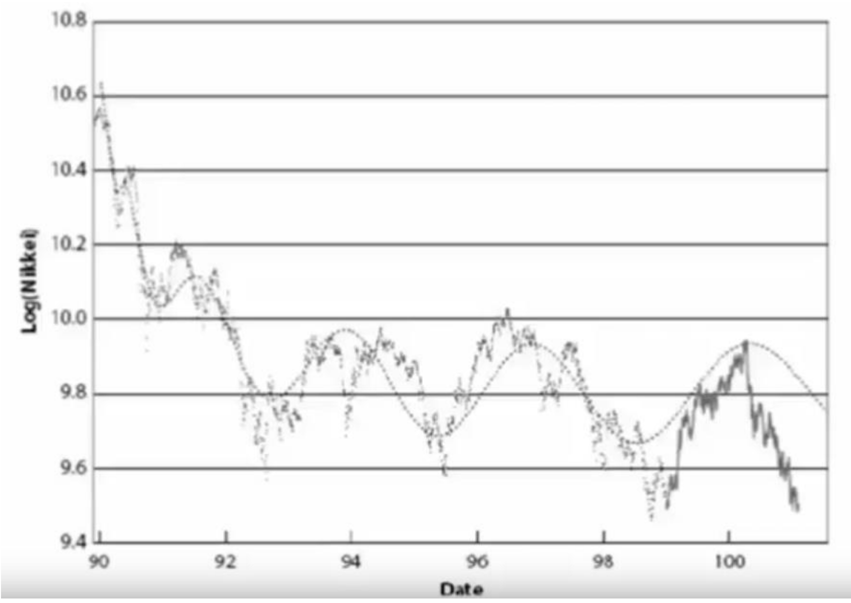
02:12, the second graphs for medicine.



02:30, the same graph, here with red lines added to make it easier for the student watching to follow the audio narrative.

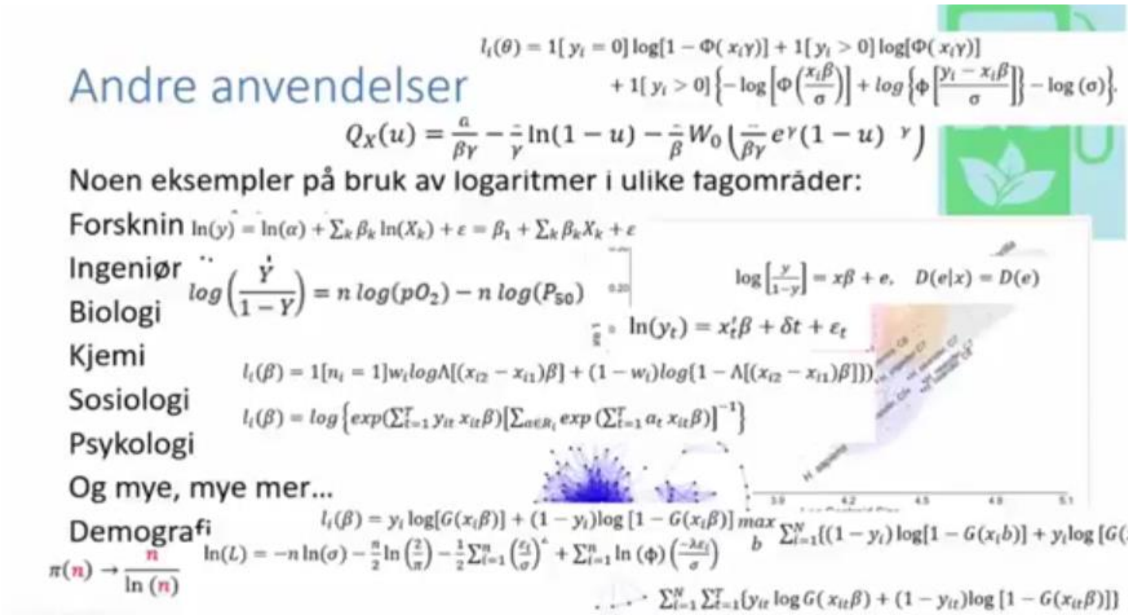


02:47, fourth part, the first graph from economy. This graphs is used to demonstrate that semi-logarithmic plots are used outside of medicine, and to show that some graphs turn out almost linear when presented logarithmically. It is not mentioned that the graph is exponential. Because I assume this will make it too difficult for the student to follow.

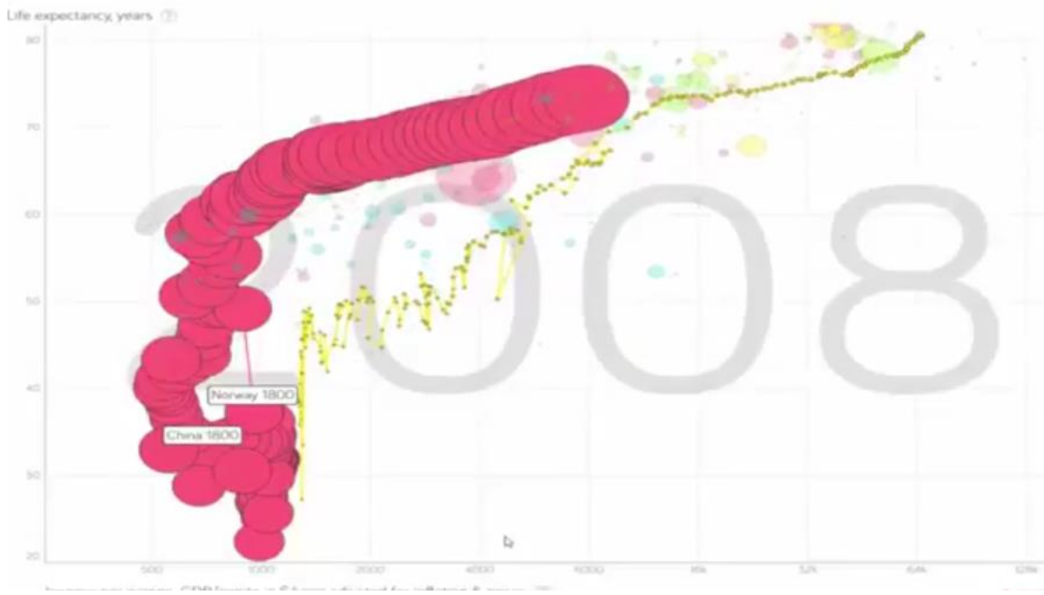


03:03, the second graph from economy. This, too is used to demonstrate the existence of logarithmic plots in various disciplines, and the details are not discussed.

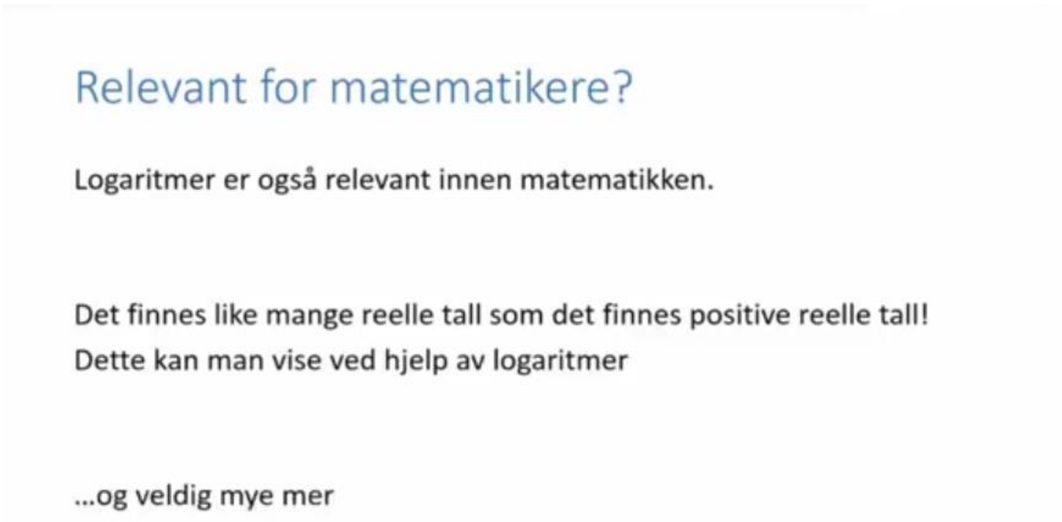
03:11, fifth part, summary of applications. It is mentioned that logarithms are used in many different ways and fields, in the hopes that the students watching will understand that (semi-) logarithmic plots are only one of the ways logarithms are used.



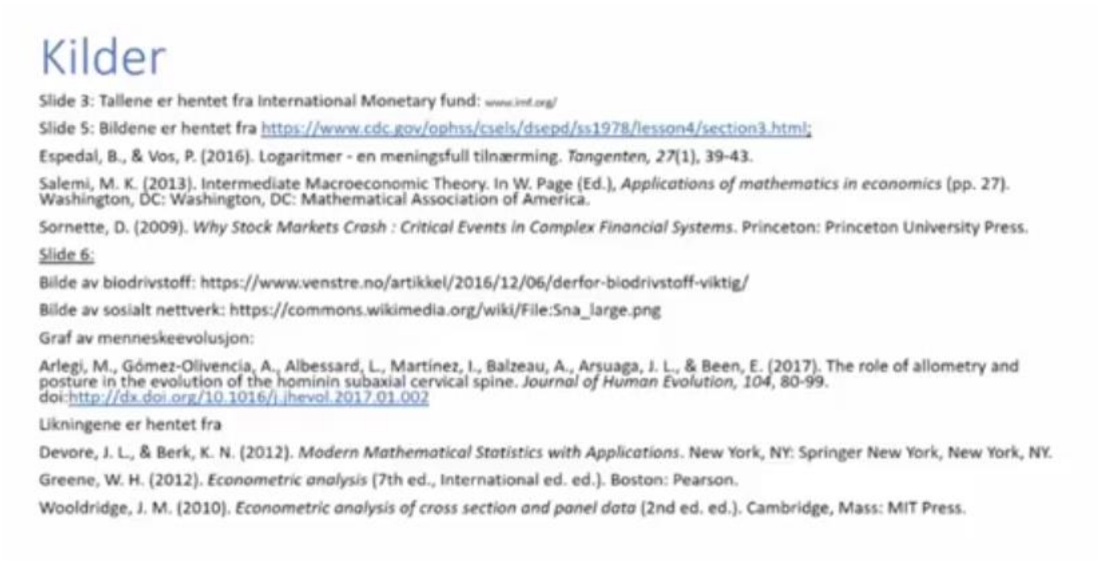
03:24, the fifth part as it appears at the end. This part summarizes the uses of logarithms: the fields where they are used starting with sciences that are typically associated with mathematics (research in renewable energy, engineering, biology, chemistry), and ending with disciplines that may not be viewed as connected with mathematics (psychology, sociology, demography). The fact that logarithms are used in different ways is demonstrated by the equations that pop up, aiming to demonstrate that logarithms are used in other ways than just plots.



04:22, the sixth part, an animation from Gapminder with an audio narrative. The graph is complex, so written text is held at a minimum, and the cursor is used to help the students focus.



04:37, seventh part, discussing the relevance of logarithms within mathematics. The example that I use is that the cardinality of real numbers equals the cardinality of the positive real numbers, a consequence of the homomorphism between these two sets, which can be established by logarithms.



04:42, the last slide, with sources and references.

12.6 Interview Guide
Masteroppgave våren 2017

Intervjuguide

Husk: Lydopptak, skrivesaker
Husk Kvales kriterier (Kvale & Brinkmann, 2015, pp. 195-196):

1. Kjent med fokuset i intervjuet
2. Struktur: oppgi meningen med intervjuet
3. Klare enkle, korte spørsmål
4. Gentle: La eleven fullføre, gi tid til stillhet
5. Følsomt: Hør på hva som blir sagt, vær interessert, fang signalene
6. Godta hva eleven sier, ha tid til ting som er litt på siden
7. Styring
8. Kritisk: Vær forberedt
9: Huske: Bruk notater underveis
10. Tolkning: Bør undersøke hva eleven mente i selve intervjusituasjonen

Selve intervjuet: semistrukturert intervju

1) Meningen med intervjuet er å undersøke hva du/dere tenker om og mener er relevansen av logaritmer. Det er viktig at elevene får tid og rom til å si det de mener, med sine egne ord.
2) Anerkjenne elevene; forklare kort hvorfor nettopp denne/disse elevene ble valgt ut til intervju (gir gode refleksjoner, muntlig aktiv, flink til å sette ord på tanker)
3) Husk å stille klare, korte og enkle spørsmål og gi eleven tid til å tenke seg om, og vis interesse for det eleven sier.
4) Kom med oppfølgingsspørsmål til det eleven sier
5) Unngå ledende spørsmål
6) Be om oppklaringer på alt som kan være uklart.

Mål med intervjuet:

1) Bli kjent med elevene, skaffe informasjon om ambisjoner (motive?), bakgrunn, tanker om matematikk og matematikkens relevans
2) Finne ut av hva elevene tenker om materialet som ble presentert. Var det interessant? Belysende? Motiverende? Relevant?

Strukturen i intervjuet

1) Forklar hensikten med intervjuet, takke for deltagelsen
2) Elevbakgrunn: snakk med en elev av gangen
    a. Hvorfor har du valgt R1?
    b. Har du noen spesielle ønsker/ambisjoner/mål for videre utdanning eller karriere?
        i. Oppfølging: Hva er grunnen til det?
    c. Har du noen tanker om matematikk og relevans?
        i. Oppfølging: relevant for hva? Personlig/studier/arbeid/samfunnsdeltagelse/annet?

3) Du har nylig lært om logaritmer, og vi skal snart snakke mer om det. Før vi går videre vil jeg vite om du har noen tanker om dette. Ut fra det du vet, det du har lært og dine tanker, har du noen refleksjoner om relevansen av logaritmer? Er det relevant for deg? Er det relevant for noen i klassen? Burde det være en del av læreplanen?
4) La han/hun se filmen. Gi tid til å tenke seg om, gi mulighet for å spørre etter oppklaringer
5) Finn ut av hva han/hun tenker om filmen:
    a. Var noe vanskelig å forstå?
    b. Noe du savnet/ synes burde vært annerledes?
    c. Var det som ble nevnt i filmen noe som du kan relatere deg til/ Relevant for deg?
    d. Tror du at dette kan hjelpe deg til å bli mer motivert i å jobbe med matematikk generelt og logaritmer spesielt?

12.7 Transcription Key

Appendix 12.7 Transcription Key

Symbols and abbreviations used in the transcripts (appendices 12.8.1-4)

Symbol	Explanation
A:, B:, C:, D:, E:, F:, G:, H:, I:, J:	Interview objects, anonymised short index (A and B are used for group 1, C and D for group two and so on). Letters followed by colon are used for indicating who is talking.
Int:	Interviewer is talking
André, Bjørn, Christian, Daniel, Emilie, Fredrik, Gjertrud, Hilde	Interview objects, anonymised full names. Full names are used to indicate the use of names during the conversation. André corresponds to A, Bjørn corresponds to B and so on. Male names are used for boys, feminine names for girls.
[A closes door]	Actions in square brackets indicate that an action takes place. Letter indicates who is performing the action. Example: André closes the door.
(5:00)	Indicated where in the recording this is. Example: 5 minutes after start.
(text)…(text)	Minor break, less than one second
(text)…	Sentence not completed
A: (text)… B: (text) A: …(text)	The use of dots indicated that the speaker was interrupted. Here, A is interrupted by B and in the last line, A continues talking.
Bold Text	Bold text indicated that it is quoted in the results
Italicized text	Italicized text indicated emphasis. Rarely used.

12.8 Transcriptions
12.8.1 Group 1: Andrè and Bjørn

Int: Ja!
[Utydelig]
A: Snakke om de viktige tingene
B: Logaritmer er jo det viktigste
Int: Ja, ok. Aller først, tusen takk for at dere sier ja til dette.
B: Ja da
Int: Det er jeg veldig glad for.
B null problem
Int Så det jeg vil gjøre nå det er å først bare prate litt om dere, bli litt kjent med dere, finne litt bakgrunnsinformasjon,
B Ja
Int så skal vi etterpå se den filmen jeg har lagd, og til slutt snakke litt om den filmen, for å finne ut av hva dere tenker om den.
A mhm
B mhm
Int Ok
Int Ehm… så vil jeg bare for min egen del… du var Bjørn?
B mhm
Int Ja… da skriver jeg en B der… og André det var A…
A Ja
Int Ok, så kan jeg huske navnene. Det var fint. Da kan jeg begynne med deg, Bjørn. Hvorfor valgte du R1-matte?
B: Ehm, nei, jeg gikk jo… æ …vi er jo 00-ere begge to, så vi gikk jo 1T ett år tidlig. Så da
Int Ja
B: så trives jo greit med matte og får gode karakterer, så ble det jo naturligvis det….
Int: Ja
B: Gode.. Du preppes godt til fremtiden, får litt studiepoeng, og,… det er det eneste du kan ta ett år tidlig, du kan ikke begynne på S ett år tidlig.
Int Mhm
B: så det går helt fint det
Int: Ja. Veldig fint. Så du går… du er altså førsteårselev, du går VG1?
B: Ja
Int: Mhm, veldig fint. Og da gjør du også det, André?
A: Ja, er veldig lik, veldig like historier.
Int: Ja. Ja. Ehm… da har dere noen spesielle… Ja, kan ta André først, nei beklager, Bjørn, Bjørn først, Har du noen spesielle ønsker eller ambisjoner eller mål for fremtidig utdanning eller jobb, karriere eller sånt?
B: Jeg er jo litt sånn veldig usikker på videre utdanning da, men jeg tenker jo at det blir jo veldig sannsynlig at jeg går en eller annen form for høyskoleutdanning, og den vil mest sannsynlig være rundt noe realfaglig vil jeg tro.
Int Mhm
B: men jeg vet ikke så mye mer enn det egentlig, er litt usikker på det
Int: Nei
Int: Når du sier høyskole, mener du høyskole eller universitet eller?
B: Ja, høyskole eller universitet
Int: Mhm, ja
Int: Så noe realfaglig?
B: Ja, det er det jeg trives best i
Int: Ja. Det er ikke noe sånt, ikke Ingeniør eller medisin … Du har ikke tenkt så veldig mye på det?
B: Nei, men det er liksom… begge de to er alternativer som jeg har liksom tenkt litt på, men jeg vet ikke, men jeg har ikke slått meg fast med noe som helst egentlig..
Int: Nei, veldig fint. Og du da, André?
A: Nei jeg har heller ikke… jeg er veldig usikker egentlig på hva jeg skal gjøre.
B: hmm
Int Ja
A: Men.. ja… Nei… jeg skal jo… jeg har jo tenkt å få liksom… å studere no… jeg er veldig usikker
Int mhm

A: men .. det er ganske sannsynlig at det blir noe med matte eller realfag
Int: Ok
A: I og med at det er de fagene jeg er mest i
Int. Ja. Det er jo lov å interessere seg for andre ting og.. Det er jo folk som blir psykologer og andre ting også… men det er realfag som er tingen for dere begge….sannsynligvis?
B: Ja
A: mest Sannsynlig
Int: Hvis det skulle være noe annet enn realfag, bare for å ta det temaet? Hva kunne det vært?
A: jeg hadde studert idrett
Int: Ja
B: Ja det kunne vært idrett for meg også hvis jeg fikk liksom muligheten, men det kunne også vært sånn dærre sosialantropologi eller psykologi, det er ting jeg sånn halvveis interesserer meg for altså
Int: mhm mhm, ja, ja veldig fint
Int: Har dere noen tanker om den matematikken dere lærer, nå i klassen her, hvordan den, altså hvorfor dere lærer om akkurat det, hvorfor dere lærer om for eksempel logaritmer?
B: haha, jeg tenker jo, sånn, når man kommer til matte på sånn dette nivået, så, at alt ikke har en direkte effekt på det praktiske livet generelt i alle fall, men det er litt sånn mer sånn teste … **forståelse og trene hjernen på andre ting og kanskje videre på jobber som krever litt sånn avanserte ting, men ellers så har jeg ikke…** så jeg har ikke fått sånn praktisk behov for å… kunne derivere en funksjon eller noe sånn liksom…
Int nei, nei
B: så men det…. Jeg tenker det matematikk går jo egentlig bare på å teste forståelsen og teste hvordan hjernen kan sette sammen Mønster og ting og tang
Int: ja,
B: rett og slett
Int: hva vil du si…
A: ja, jeg tror det er mye av det også liksom… bare å ha grunnlaget til videre studering igjen
Int: Ja
A: men jeg vet liksom ikke… hvordan jeg skal bruke dette i en jobb
Int: Ja
A: Ikke enda hvertfall
B: i Dyreparken
Int Derivasjon i…
B: i dyreparken [ler]
Int og H: [Ler]
Int: Ja… For det er akkurat der …mitt arbeid kommer inn. Det er å forsøke å koble det dere lærer med hva det faktisk brukes til..
B: ja
Int ja…. Så… ja!... så er det over til neste del da… ja en ting til, en ting til… Hvis en skulle si at matematikk er relevant, hvis jeg sier at logaritmer er relevant for deg… hva vil i så fall det bety?
B: ehhh om det er relevant i en praktisk sammenheng… **jeg føler liksom… jeg har aldri tenkt på logaritmer som noe relevant i sånn en direkte sammenheng, som hvis jeg er ute et sted og i en situasjon… så tenker jeg oi nå må jeg tenker logaritmer for å finne ut av hvordan jeg må gjøre noe nå…men som med alt så er det trene hjernen, IQtrening, testing og se ting i sammenheng…**
Int: ja. … ehm… og tenker jeg også litt at en har det med at …. Ting kan jo være relevant fordi en skal studere det,
A&B: ja
Int. kan være relevant fordi en skal jobbe med det
A&B: ja
Int: kan være relevant for deg personlig, du har en eller annen interesse som går på dette…
A mhm
Int: Og ting kan være relevant fordi en skal være en samfunnsdeltager…
B: mhm
Int: altså noen ganger så kan logaritmer dukke opp i forskjellige sammenhenger ehm… jeg skal ikke avsløre for mye…
B: [ler]
Int: men plutselig står det noe i som.. i en avis som kan ha noe med logaritmer… det skjer! Hele tiden…man tenker kanskje ikke på det.
A nei
Int: men da er det jo kanskje nyttig… å bare være en del av samfunnet, å vite litt om matematikken….

B: nei
Int: Nå tok jeg kanskje ordene ut av munnen på dere
B: Å ja, men du sa det s godt selv… jeg er spent på den logaritmefilmen altså…
A&B: [ler]
Int: Da går vi over på filmen…da står den innspillingssaken og durer i bakgrunnen… Jeg kunne vært bedre forberedt ser jeg
B: vi har jo god tid sånn sett
Int: Dere synes ikke det… Matte er ikke utfordrende for dere? Eller?
B: nei ikke egentlig
A: nei, altså, det er ikke det faget jeg jobber mest med…det er sånn forventa
Int: mhm
B: nei, jeg får jo toppkarakter… og trenger ikke, treger ikke være der nå…
A: Det er noe med det…
B: Skal ikke skade karakteren min det…
Int: nei…
[filmen starter]…
…[Filmen slutter]
[11:55]
Int: Ja! Noe som var uklart? Spørsmål?
B: Nei, det var veldig klart…
A: stoppe den greia… [Stopper filmen]
B: [Ler]
Int: Åja! Takk!
Int: Tanker?
A: Nei altså… **den hovedgreia, det var kanskje.. det .. åssen man kan… i et sånnet diagram da, vise mye bedre hvordan forskjellene faktisk er**… sånn hvis ikke blir det jo veldig vanskelig.…som du sa da, så blir det veldig vanskelig å skille… noe som kanskje det er veldig stor forskjell, siden de største tallene er så utrolig store…
Int: mhm mhm
A: Så.. ja
B: det var, det var veldig mye på … som du sa de… **hvis du skal tolke informasjon som en samfunnsborger, så er det veldig nyttig å se logaritmisk på ting, hvordan vi kan vise en mye mer realistisk sammenheng…**
Int: ja… var det noe nytt for dere, eller var dette noe dere visste om fra før av?
A: jeg visste om det fra før av, men det er ikke sånn at jeg har tenkt på at det liksom er …
B: mhm
A: …logaritmer… Det er ikke alle som kanskje heller vil skjønne liksom sammenhengen av hvor mye, forskjell det er liksom.
B: Ja liksom jeg har sett sånn… jeg har jo alltid sett grafer som….som eventuelt ikke er helt sammenhengen… men det er jo sant det, det går jo etter logaritmer da hvis det er sånn ti, hundre…
A: Det er også veldig nyttig at man kan sammenlikne forskjellige sykdommer som har helt ulike, har helt ulike sannsynligheter liksom, og allikavel så får man en realistisk sånn visning av hvordan de endrer seg. For hvis ikke hadde jo de som er veldig sjeldne bare vært, sett ut som en strek på bunnen.
Int: Ja, bare blitt sånn klumpa sammen helt der nede.
Int. Noe annet dere vil si om filmen?
B: nei, det var en grei film altså. Godt forklart.
A: [ler]
Int: ok, ja
Int: Er det noe dere savner i filmen? Noe som dere satt igjen med, hvorfor sa hann ikke noe om det?
B: Nei, jeg føler, føler det meste av den praktiske effekten til logaritmer og sånt som er kommet med der…
A: Man kunne jo gått inn på hvert liksom, hver jobb og sånt, men det hadde tatt ekstremt lang tid sikkert, så… Det er det på en måte som er daglig…Liksom, ja
Int: Ja. I forhold til de temaene som ble tatt opp nå, da snakket vi kanskje mest om medisin og økonomi, dødelighet, spedbarnsdødelighet, noen økonomiske grafer, og vi hadde noe om demografi, befolkningsutvikling i norge og kina,
A&B: ja
Int: Føler dere at det er noe dere kan relatere dere til? altså betyr det noe for dere?
B: Det vil vel alltid bety noe, ikke det at spedbarnsdødelighet i verden er så viktig for meg nå, jeg har ikke noe spedbarn som ble født på ett kilo, så
A&B: [ler]

Int: nei
B: men.. for eksempel, vi har jo**… i samfunnsfag eksempelvis så lærer vi mye om demografi og det å kunne vite en sånnen sammenlikning mellom økonomi og levealder det er jo… det er jo veldig praktisk anvendelig i forhold til vår skole**
Int: Ja mhm
Int: på dette bildet tar vi opp en del løse tråder. Er det noen av disse temaene dere vil si dere interesserer dere for? Forskning på fornybar energi, ingeniørvitenskap, biologi, kjemi, sosiologi, psykologi…
B: Jeg vil si sånn… blant alt, så det er nesten en slags… **det likner på en tilnærmet toppliste over yrker som kunne være relevant altså..**
Int Ja
B: så…
A: Jeg synes det er ganske overraskende over at psykologi er på den lista…siden det er såpass liksom mentalt fag da holdt jeg på å si…i forhold til kjemi og sånne ting
Int: Det er noe av det som overrasket meg også, da jeg begynte med dette her og finne ut av hva bruker man logaritmer til. Det var hvor mye for skjellig det er. Jeg kan si, akkurat i forhold til psykologi, så går det mest på at sansene våre er logaritmiske.
A&B: ja ok
Int: Så når vi hører noe, hvis du tidobler lydstyrker og så hundredobler den, eller, ganger med ti og ganger med ti en gang til, så oppfattes det som samme økning for øret vårt.
A: ja ok
Int: Og det samme med lysstyrke, sanseinntrykk, ja veldig mange forskjellige ting
B: ja det er greit å vite [ler]
Int: ja, kanskje
B: det visste jeg ikke fra før av hvertfall [ler]
Int: Nei, nei
Int: Tror dere sånne filmer kan hjelpe med motivasjonen i matte?
A: kanskje litt
B: jaa
Int ja?
A: det er jo greit å vite hvorfor man lærer ting
Int ja ja
B: Jeg sliter ikke med motivasjonen i matte generelt liksom, det er greit, når [the teacher] forklarer så skjønner jeg det meste så jeg slipper å jobbe så sykt mye med det og… så liksom matte er ikke noe hatfag for meg…
Int Ja
B: Men ellers så hjelper det jo å få vite… desto flere praktiske anvendelser desto bedre er det jo…
A: mhm
Int Ja! Noen siste tanker, noe mer dere vil si?
A&B: nei…
A: ikke sånn…
Int Dere to, nå forstår jeg at dere begge går i VG1 nå. Hvis vi skrur klokka tilbake ett, to tre år, når dere gikk på ungdomskolen. Føler dere da at denne typen hjelpemidler i undervisningen ville vært mer til hjelp kanskje?
A: ja sånne filmer og sånt?
Int mhm
B: jaa kanskje…. Jeg var kanskje litt mindre motivert i tiendeklasse. Det hadde vært litt sånn greit å se det i en sånnen praktisk sammenheng da liksom. Sånn at du kunne få litt mer motivasjon, se at oi det er kanskje noe du får bruk for, men…
Int ja
B: Da også gikk det jo fint. Og jeg jobbet ikke så sykt mye med matte, jeg fikk jo, på ungdomskolen fikk jeg jo femmer et par år så...
A: Oi
B: ja ikke sant
A: sykt
B: Så da, da gjorde jeg liksom ikke så mye ut av det. Så jeg trengte liksom ikke noe motivasjon på meg.
Int nei, nei
B men.. ellers så er det jo alltid greit å vite at det du holder på med ikke er ubrukelig. Det hjelper alltid på saken.
[snakker i munne på hverandre]

A På ungdomsskolen så er det mange liksom temaer og sånt som er mer relevante i oppgavene enn på videregående. Det er liksom, det er på videregående, så kommer det ikke ja det er en bondegård, liksom sånne ting, som det er på ungdomskolen.
B: ja
A: så da er det lettere å se kanskje sammenhengene da
Int i hvertfall for dere som har R-matte, litt annerledes på p-matten
A: ja, men ja, Det vet jeg ingenting om
A&B: [ler]
Int føler dere at dere har noe mer på hjertet nå?
A&B: nei
Int: Nei. Tusen takk for intervjuet, tror dere, tror det var veldig nyttig for… meg
B: [ler] jess
Int: Da kommer jeg om litt og tar inn en ny gruppe
[døra smeller idet de går ut]

12.8.2 Group 2: Christian and Daniel

Int: [whistles to confirm that the equipment is working]
Int: Ja, veldig bra. Ok Tusen takk for at dere kom, tusen takk for at dere tar dere tid til dette. Det er jeg veldig glad for. Nå vil jeg først …skal vi bare snakke litt … og skal jeg prøve å bli litt kjent med dere, finne ut av hvem dere er. Etterpå skal vi se filmen og til slutt skal se… snakke litt om den. Hva dere har tenkt om det.
C: Kan vi begynne med deg, Christian.
C: Ja
Int: Hva er grunnen til at du har valgt R1-matte?
C: Jeg ser flere valg videre. Jeg er litt usikker på hva jeg vil velge videre…
Int: ja
C: …jeg vil ikke utelukke noe.
Int: Nei
C: Da ser… da… kommer også til… alt jeg har lyst til… i fremtiden …ekstra utdanning
Int: Holde alle dører åpne?
C: Ja
Int: mhm. Har du noen spesielle ønsker eller ambisjoner, mål for videre utdanning eller…
C: Jeg har alltid en drøm om å gå en …ingeniørlinja for eksempel… ta mariningeniør og sånt, noe jeg alltid har ønsket. Men.. jeg vet ikke ennå.
Int: Nei… Ja. Hva er grunnen til at du er akkurat interessert i ingeniørveien da eller noe sånt som det…?
C: jeg liker å tegne ting, være kreativ, se på bygninger, hvordan de er bygd.
Int: Ja
C: Båter spesielt, hvordan de bryter bølger, hvordan de klarer å holde seg over vann, ikke går under, sånn
Int mhm
C: Ja, egentlig det. Liker å være kreativ.
Int: Har du noen tanker om den matematikken du lærer nå i kjetil sine timer, og hvordan den kan brukes, altså hva som er koblingen mellom det du lærer og den matematikken som faktisk brukes utenfor klasserommet?
C: ehh jeg tenker at spesielt den matematikken vi lærer nå, for eksempel får vi bruk for i fysikken. At det ideelt får til med… åssen vi regner ut der. Hvordan finne ut…
Int.. ja. Og spesielt i ingeniørfag er det masse matematikk. Det kommer vi ikke utenom.
Int: Og så til deg, Daniel. Hva er grunnen til at du valgt R1?
D: Det er jo veldig mange av de samme grunnene som Christian. At jeg har lyst til å holde alle linjer åpne. Fordi jeg vet egentlig ikke hva jeg skal jobbe med videre. Så da tenker jeg at jeg skal holde så mange muligheter åpne som mulig. Så jeg kan.. aldri får noe utelukket. Hvis det er noe jeg plutselig bestemmer at jeg vil gjøre.
Int: Ja
D: Også kan du jo også si at det er litt på grunn av press kan en si. Fordi har alltid gjort det godt tidligere i matte. For da blir det nesten litt … hva skal jeg si… litt rart å velge noe enklere matte synes jeg.
Int: Du sier press. Hvem kommer det presset fra i så fall?
D: Nei, det er jo fra foreldre så klart, også end del fra vennegjengen. Det er jo veldig mange som gjør det veldig bra der. Jeg vil jo på en måte holde meg på samme nivå, ikke sant.
Int: mhm. Har du noen ønsker eller ambisjoner for videre utdanning eller yrke, karriære?
D: Nei, det er vel bare å ha en forholdsvis høyt utdannet jobb som jeg kan leve godt av. Og som jeg har det gøy med. Det er ganske viktig synes jeg.
Int: mhm, ja. Noen retninger du ser for deg?
D: Ehm, forløpig så som jeg sa så vet jeg ikke helt. Men noe ingeniørlinjer kunne vært noe tenker jeg.
Int: Ja. Mhm. Er det… hvis jeg sier for eksempel realfag kontra språkfag eller humanitære fag… har du noen tanker i forhold til det spekteret.
D: Ja, det er mye mer på realfag. Jeg er veldig glad i kjemi, biologi…jeg har egentlig fullt realfag i år. Det er egentlig bare realfag jeg satser mest på.
Int: Ja, ja. Takk for det. Har du noen tanker om forholdet mellom den matematikken du lærer nå i kjetil sine timer, og gjerne også andre mattekurs du har tatt tidligere, og hvordan matematikken brukes ute i samfunnet?
D: Ja det har jeg faktisk. Jeg tenker at veldig mye av den matten vi har nå, det er jeg føler at den ofte kan komme litt som overflødig, kanskje at jeg ser ikke noe bruksområde for akkurat denne typen matte. Men så klart, på mange temaer ser jeg at dette kan være brukbart. Sånn som det vi har nå med derivasjon, å finne sånn stigning over alt mulig, kan jo være relevant tenker jeg. Men samtidig har du jo de unødvendige punktene også.
Int: Ja. Hva vil du si er et unødvendig punkt, et eksempel?
D: Jeg vet ikke om jeg kommer på noen på sparket her akkurat, men… nei, jeg har ikke noe akkurat nå.
Int: Det er helt greit. Til dere begge, logaritmer spesielt. Hva tror dere det brukes til?

D: Logaritmer ja… Ja det var faktisk et av de punktene som jeg ikke var så sikker på om er brukbart videre.
Int: Ja. Så det går i den diversekassa som vi ikke bruker til noe.
D: ja, ja det tenker jeg. At hva skal jeg bruke det til liksom. Jeg føler det er veldig sånn spesifikt, jeg føler at det er ikke veldig brukbart nesten.
Int: Ja. Har du noen tanker om logaritmer?
C: Litt av det samme. Jeg ser ikke helt behovet. Det kommer inn når du skal for eksempel gjøre en oppgave for eksempel i en arbeidsstilling. … men som sagt jeg vet ikke. Jeg har ikke gjort en stor arbeidsstilling.
Int: Nei
C: Så ehh.. det kan være mye som er bak logaritmen som ligger dypere som vi ikke… uansett får bruk for.
Int: Ja. Nå snakker jeg om… bruk som… blir tolket som umiddelbart i arbeidsammenheng. Kan jo også være at det er nyttig kun for studiene sin del. Og det kan være nyttig for helt andre ting. Det kan være du er personlig interessert i det. Eller at det hjelper deg som samfunnsborger. Altså når du skal delta i sammfunnet, at kunnskap kan være nyttig.
D. Jaja, så klart.
Int: Ja. Legger du til noe mer på lista da?
D: ehm.. ikke noe spesielt som jeg tenker på nå nei..
C: Nei, ser ikke noe på det
Int: Nei. Nei. Helt i orden. Det er jo litt av grunnen til at jeg kommer inn her med mitt prosjekt. Fordi akkurat som dere sier, det er litt vanskelig å se hvorfor i all verden lærer vi om akkurat om dette her. Kan se litt ubrukelig ut. Målet med det jeg gjør nå er å forklare hvordan det faktisk brukes.
D: mhm
Int. Så da vil jeg at vi skal se på filmen min.
[lyder mens jeg setter opp filmen]
Int: er det greit sånn?
C&D: Ja
(6:49)[starter filmen]…
…[Filmen er ferdig]
(11:33)
Int: Ja. Skal vi se…
Int: hva tenker dere?
D: Jeg synes den var veldig god og informativ. **Den gjør jo noe som skolen ikke gjør, som er å opplyse hvorfor vi trenger ting. Det er faktisk noe jeg ser på som et veldig stort problem**. At vi får lært veldig mye forskjellig, men ikke lært bruksområdene. Så ja, jeg synes den var veldig nyttig. Det kom veldig mye god fakta ut av det.
C: tenker det at.. viser veldig greit hvordan vi får bruk for det i fremtiden. ehh hvordan… viser spekteret, i stedet for en måling med det vi gjør. Istedenfor å bare lære en masse tall.
Int: Ja. Bare for å være klar på hva du mener, hva mener du når du sier en måling?
C: Ja.. at vi har et mål for hva vi lærer.
Int: Riktig. Ikke at vi måler desiliter men…
C: Ja.
Int: Veldig fint.
Int: Er det noe som var uklart, noe dere lurer på?
D: Nei altså, jeg synes den var veldig klar og informativ. Det var ikke noen spørsmål igjen etterpå synes jeg
C: Nei
Int: så greit [ler]
Int: Så det var klart. Det var ikke noe som var… Var det noe som var vanskelig å forstå? Nei. ja?
D: Nja, **kanskje litt avanserte eksempler** av og til men…såklart det går jo fra person til person.
Int: Ja. Hvilke eksempler tenkte du på da?
D: Nei, jeg tenkte litt på **det med BNP**. Det var en litt spesiell graf synes jeg.
Int: Ja
D: Eller det var vel heller forventet levealder, den med Kina og Norge.
Int: Ja, den animasjonen
C: Den viste vel både økonomisk og levealder.
Int: mhm mhm ja. Det kan være litt vanskelig når du får to forskjellige ting på samme…
D: Ja.
Int: Når du sier Brutto Nasjonalprodukt…Var det ikke den du… var den den du mente?
D: Nei jeg tenkte bare feil. Jeg mente egentlig den med Norge og Kina.
Int: Ok, ok. Ja men da så. Og du , var det noe som du synes var vanskelig å forstå?

C: Nei, jeg synes det var greie eksempler.
Int: Ja.
C: hvor det vises.. hvor vi bruker logaritmer…
Int: Er det noe dere savner i filmen? Noe dere skulle ønsker var der som ikke var der?
C: det viser jo veldig sånn.. historiske tall, men jeg ser fortsatt ikke noe praktiske behov jeg ville for eksempel brukt i en vanlig manns hverdag.
Int: Nei. Hva tenker du da?
C: Jeg ville ikke lagd en graf når jeg kommer på jobb.
Int: Nei
C: Vil ikke jeg se på.
D: Det føles litt spesifikt ut på en måte, litt ut som en nisje innenfor en viss utdanning.
Int: mhm
D: Men likavel, for de det gjelder for var det veldig informativt synes jeg.
Int: mhm mhm. Kunne dere ønske dere at… i forhold til dere sier nå da… hvordan kunne det vært gjort annerledes?
D: tja.. jeg føler ikke det kan gjøres så mye mer med det egentlig… Det er jo ikke så veldig bredt område egentlig med logaritmer, så jeg føler det egentlig fikk med alt.
Int: Ja. Christian, hva tenker du?
C: Ehh.. jeg tenker at du fikk vise… at vi får brukt logaritmer på en grei måte… **At det har bruksområder i det hele tatt.**
Int: Det var kanskje det viktigste, at det er bruksområder i det hele tatt?
C&D Ja
Int: Var det noe i denne filmen som dere personlig kan relatere dere til
C: …tenker på et økonomisk point ehh så kan det greit vise for eksempel et bedrifts økning eller synkning i økonomien…
D: Ja, føler ikke det ligger helt personlig. Ofte når jeg lager sånne grafer i forskjellige matteoppgaver så blir det ofte litt unøyaktig, kanskje litt dårlig fremstilling. og dette viser det jo veldig mye bedre synes jeg
Int: ja
D: Så jeg ser jo for all det nyttigheten til det.
Int: Ja, veldig fint. Tror du at sånne filmer som dette her, som ikke ser på det tekniske i det hele tatt, men kun ser på hvordan ting brukes, at det kan være en nyttig del av undervisningen?
D: Det tror jeg virkelig faktisk. **Jeg tror vi trenger å vite hva vi bruker det vi lærer til. Det kan også hjelpe veldig mye med motivasjon faktisk.**
Int: Ja. Ja. Christian, hva tenker du?
C: Jeg tenker at hvis du får koblet hver av formlene til hva man bruker logaritmer til, eksemplene så man ser bruksområdet, et praktisk bruksområde så man må tenke seg rundt formelen, i stedet for å bare se enda en formel i logaritme.
Int: Ok. Du kunne kanskje sett litt mer hvordan den tekniske prosessen foregår, hvordan vi bruker logaritmer?
C: Ja hvordan vi får… hvorfor vi bruker denne formelen, hva den skal brukes til
Int: ok. Noen tanker til slutt?
D: Ehh, nei. Har egentlig ikke noe mer å legge til.
Int: Nei, nei. Du har sagt det du har på hjertet. Christian?
C: Godt informert
Int: Ja
C: [Uklart]
Int: Takk for det! Da tror jeg det… Da var det jeg ville si! Takk for deltagelsen!
D: Ja, det var null problem. Det var gøy dette her. Litt variasjon i mattetimene, trenger det!

12.8.3 Group 3: Emilie and Fredrik

Del 1
Int: … den knappen, da tar den opp lyd,
F: ok
Int: så nå hører vi hva dere sier. Ikke noen andre enn meg da. Men, ehh, nå har vi det på fil, jeg har lagret det.
Int: Nå vil jeg bare aller først prate litt med dere, bli litt kjent med dere, finne litt ut om hvem dere er. Så etterpå skal vi se den filmen jeg har laget, og til slutt snakke litt om den. Ja. Ehh.. også bare litt for å hjelpe meg. Der var Emilie, var det ikke det?
E: Emilie.
Int: Emilie. Og ditt navn var …
F: Fredrik
Int: Emilie og Fredrik. Da kan vi begynne med deg, Emilie. Ehm, hva er grunnen til at du valgte R1-matte?
E: Eh, for jeg tok 1T i fjor, og det gikk sånn passe greit, så ja.
Int: Ja, så da
E: var det
Int: Det var R1 det naturlige neste steg?
E: Ja
Int: Har du noen spesielle ønsker eller ambisjoner, mål for videre utdanning og jobb, karriere?
E: Ehm, jeg vet ikke hva jeg skal bli, men jeg skal ta IB til neste år og så kanskje NTNU
Int: Ja
E: Hadde vært gøy
Int: ehh… Så NTNU altså… tenker du noen tekniske fag, naturvitenskaplig, ingeniør…
E: Ja, ish
Int: noe sånt
E: Ja
Int: Ja, mhm.
F: mhm
Int: veldig fint. Og når vi snakker om dette med relevans, har du noen tanker om den matematikken du lærer av kjetil og kanskje også den du lærte i 1T-matten og ungdomsskolen og relevans, altså hvordan dette faktisk henger sammen med hverdagen utenforbi klasserommet?
E: Ikke så veldig mye [ler]
E: Nei, ikke så veldig.
Int: Nei. Når du for eksempel lærte om logaritmer, før vinterferien, tenker du at dette kan brukes til noe?
E: eh… jeg har ikke tenkt på det…
Int: Nei. Helt i orden.
Int: Og så deg, Fredrik, var det det?
F: Ja
Int: Hva er grunnen til at du har valgt R1?
F: Ehh… egentlig bare … **det er liksom en fortsettelse. For jeg har alltid gjort det bra i matte…**
Int: Ja
F: … og **så hadde jeg T, så gikk jo det greit, så da tenkte jeg at det ikke så mye annet som var relevant enn R1**
Int: Nei. Da var det det naturlige steget videre?
F: Ja
Int: Ja. Og har du noe du har veldig lyst til å studere eller jobbe med?
F: Nei! **Så jeg prøver bare å holde dørene åpne**
F: Liksom…
Int: ok
F: mhm
Int: hvis jeg da sier, altså, realfag kontra språkfag kontra helt…
F: helt! Ja.
Int: Ja
F: ingen anelse
Int: så du kan like gjerne bli professor i nordisk som du kan bli bussjåfør som du kan bli ingeniør?
F: ehh… Ja
E&F: [Laughs]
Int: Ja, men det er …
Int: Nei. Har du [Looks ar Fredrik] noen tanker om matematikken du lærer her og…

F: Relevans, liksom?
Int: …ja, ja
F: jeg tenker ikke mye på det når jeg driver med det her
Int: Nei
F: Med det nærmeste har vel kanskje vært i fysikk og kjemi, som jeg har nå i år,
Int: Ja
F: Hvor det blir liksom litt relevant, for det er litt mer teoretisk til hvordan verden fungerer og er satt sammen liksom
Int: Ja
F: Og når det vi har lært i matte kommer igjen der så ser jeg litt større sammenheng enn det jeg gjør i bare mattetimene.
Int: Ja mhm veldig fint. Også når vi snakker om dette med relevans, til dere begge altså så jeg… snakker en gjerne … nå blir det veldig fort naturlig å koble det mot utdanning, yrke. Ting kan jo også være relevant av andre grunner. Det kan jo være relevant kanskje fordi en har en personlig interesse for noe, og det kan være relevant fordi det hjelper en som samfunnsborger i ulike sammenhenger. Har dere noen tanker i forhold til det?
E: hmm, ja… altså jeg synes jo det er gøy med matte, fordi hvis ikke så hadde jeg jo ikke tatt det. Og spørsmålet hvorfor jeg tar så mye matte, ja **så kan man hjelpe barna sine eventuelt, han lillebroren min** som typisk
Int: Ja
E: Når han skal ha det
Int: Ja, det er også noe. Nå har jo dere nylig lært om logaritmer, før vinterferien, som jeg forstod det
E: mm ja
F: Vi har jo hatt om det før og da, men
Int: Ja, i 1T?
F: Ja, mhm. Det kom opp igjen.
Int: Ja, og nå skal vi fokusere litt mer på logaritmer. Ehm...logaritmer spesielt, hva tror dere det brukes til?
F: Sånn i teori i hverdagen, eller i teorien i matten?
Int: Nå tenker… Det kan være i matten også. Både i matten, i hverdagen i nyheter, i arbeid, i forskning…
F: Det brukes i pH, det vet jeg i hvertfall! [ler]
Int: Ja! Godt eksempel!
F: ehm… noe annet vet jeg egentlig ikke.
Int: Nei, Emilie?
E: Nei jeg vet heller ikke
Int: Nei, det er helt i orden. For det er akkurat det mitt arbeid kommer inn. Og det jeg forsøker å gjøre er å skape en kobling mellom det dere lærer, og det det faktisk brukes til utenfor klasserommet. Så da tror jeg vi er klare for å se filmen, tror dere det?
E&F Ja
Int: Skal vi se … sånn … og sånn …
Del 4
[Spiller av filmen]
Del 5a
Int: … ja! Hva tenker dere nå?
E: ehh.. hvordan fungerer det i psykologi og sosiologi?
Int: Ja, ehm… bruken av logaritmer i psykologi, det handler først og fremt om at de fleste sansene våre er logaritmiske. Sånn at lyd, lys, mange av disse sansene er logaritmiske. Hvis du… hvis jeg for eksempel dobler intensiteten i en lydbølge og firedobler den, så er det det samme som å øke den opplevde lydstyrken med ett eller to hakk. Vi sier at det oppleves logaritmisk. I sosiologi er litt mer komplisert, det handler veldig mye om sånne grafer med logaritmiske akser. Ett eksempel jeg fant, det var en som forsker mye på lynsjing i USA på tidlig nittenhundretall og på slutten av attenhundretallet. Han sammenliknet ulike befolkningsgrupper og hvordan dette foregikk, og han brukte mye logaritmer i sin analyse. Og så er det sånn at i all forskning hvor hvor man driver med tallmaterialer, samler inn data og driver med statistisk analyse, så vil det, som regel i alle fall, på en eller annen måte være nyttig å bruke logaritmer i den analysen.
E: hm
Int: Ja
E: Kult!
Int:: Ja, det synes jeg også. Ehm, noen andre tanker du har etter å ha sett filmen?
E: … ikke sånn spesielt som jeg kommer på
Int: Nei. Fredrik?
F: Ehh… Egentlig ikke. **Det var egentlig som jeg hadde trodd, at det var mest i fremstillinger av statistikker.**

F: Og sånn. Gi oversiktlighet, få det i et klart system.
Int: Ja
F: Men naturlige logaritmen er noe jeg føler jeg aldri fikk en ordentlig definisjon på
Int: nei
F: Men det er kanskje ikke noe å ta her [laughs]
Int: Nei, jeg tror ikke vi skal bruke så mye tid på det. Jeg tar gjerne en forklaring etterpå, men vi skal ikke… da må jeg transkribere det etterpå, og det tar så lang tid.
F: Ja, [laughs]
Int: men.. Ja… Var det noe i filmen dere synes var vanskelig å forstå eller uklart?
F: Egentlig ikke
E: mm… **Jeg synes det var litt vanskelig å forstå hvordan de grafene fungerte**
Int: ja
E: eller hvorfor de var logaritmiske
Int: Ja. Tenker du på alle sammen da, ta for eksempel denne [peker på skjermen]
E: Ja
Int: Hvis vi tenker den briggske logaritmen, altså den med base ti…
Int: Hvis vi tar den briggske logaritmen til 0,1, log(0,1)…
E: mhm
Int: en så blir det minus en, ikke sant
E: Ja
Int: og til en så blir det null
[13:00]
[forklarer hvordan logaritmiske akser er satt sammen]
[14:00]
[snakker om hvordan grafen er laget]
[14:20]
Int: er det noe du ønsker skulle vært annerledes i filmen?
E: ehh
Int: Vær ærlig
E: ja, nja, Ikke noe spesielt. Kunne vært forklart litt bedre.
Int: Ja, akkurat det med hvorfor det er logaritmisk. Det er et fint innspill. Og du, Fredrik?
F: Jeg synes det var fint. Men jeg tenker at når du er ferdig med å snakke om en graf, så kan du la den stå oppe litt. For når du er ferdig med å snakke, er det fint å ha litt tid til å reflektere over det du har sagt, mens vi kan se på grafen.
Int: Ja, det er et godt poeng. En av fordelene med å ha en film er jo at man kan trykke på pause, men hvis man viser den på lerret i klasserommet så får man jo det problemet. Takk. Er det noe av det jeg tar opp i denne filmen som dere kan relatere dere til personlig?
E: Jeg synes det er ganske greit å få vite sånne ting. Folk spør jo alltid hva trenger du matte til egentlig, og det er jo ganske gøy å faktisk få en forklaring på det.
Int: mhm
E: Egentlig synes jeg man burde få det oftere i matten. [school activity system]
Int: Ja. Hva tenker du om det, Fredrik?
F: Ja, jeg er enig. Jeg har ikke noe mer å komme med.
Int: Ja. I forhold til de eksemplene jeg viste. Vi snakket litt om noen dødelighetsgrafer, sykdommer, barnedødelighet, økonomi, demografi, og nevnte noen forskjellige områder hvor det brukes. Er det noen av de dere er spesielt interessert i? … Fornybar energi, ingeniørvitenskap, biologi og så videre.
F: Som fag, mener du da?
Int: Som fag.
F: Jeg liker psykologi, men jeg har det ikke på skolen
Int: Kanskje vanskelig å si noe om
F: Ja. Jeg kan ikke noe om det, men jeg liker konseptet.
E: Ja. Det er jo ekstremt avansert egentlig
Int: Psykologi, ja?
E: Ja
Int: du var vel inne på det, Emilie, tror du sånne filmer kan hjelpe på motivasjonen i matematikk?
E: Ja!, jeg tror det ja.
Int: For deg personlig eller generelt? Eller begge deler? Altså for deg eller alle?
E: Ehm, begge deler.
Int: fredrik?

F: Jeg er enig. Veldig enig egentlig. Fordi man får ofte bare masse sånn pugg kaste på seg i matte. Men så vet man ikke hva man skal bruke det til. Sånn som Emilie sa i stad egentlig.
Int: Ja. Synes dere det burde være en del av undervisningen?
F: Ja
E: Ja. I hvertfall litt sånn enkelt før man begynner
Int: Ja. Noe annet dere har lyst til å si? Tanker?
F: Nei, egentlig ikke.
E: Nei
Int: Tusen takk for bidragene! Da kan dere gå tilbake!
F: Ja!

12.8.4 Group 4: Gjertrud and Hilde

Int: Så nå tar den opp lyden… nå gjør den utslag, det er fint.
H: Oi! [chair screecs]
Int: Ehm, det jeg vil gjøre nå er først å bare prate litt med dere, finne litt ut om hvem dere er, og så etterpå skal vi se filmen jeg har laget og til slutt snakke litt om den. Også bare et lite hjelpemiddel til meg selv… Hilde…
H: mhm
Int: Da setter jeg en H der… Og da var du Gjertrud.
Int: Skal vi begynne med… Nå har jeg begynt med den som sitter der, så da blir det du jeg begynne med
H: Ja
Int: Hilde, hvorfor tar du R1-matte?
H: ehm… Hvorfor?
Int: Ja?
H: Jeg vil holde mulighetene åpne for jeg aner ikke hva jeg vil gjøre videre.
Int: Nei
H: Så jeg tenkte at hvis jeg kan klare det, så tar jeg heller det, siden…
Int: mhm
H: Da kan jeg slutte etter ett år, men tar jeg S-matte, så må jeg på en måte ta S2 også.
Int: Ja. Så det handler om å holde mulighetene åpne.
H: Ja.
Int: Veldig fint. Har du noen… du sier at du… eller… har du noen spesielle ønsker eller ambisjoner for studier eller yrke?
H: Ingenting
Int: Ingenting.
H: Har ingen anelse.
Int: Helt åpent.
H Ja.
Int: Hvis jeg sier realfag, språkfag, psykologiske fag, humanitære fag, og så videre… er det noen retning du foretrekker?
H: Jeg tar jo realfag nå,
Int: Ja
H: På en måte er det jo den retningen, men så… er det jo litt vanskelige fag, så jeg vet faktisk ikke.
Int: Nei, det er helt lov. Du er absolutt ikke alene om å tenke det… Det tror jeg gjelder de aller fleste i VG2.
H: Ja
Int: Har du noen tanker om den matematikken du lærer av kjetil nå, og hvordan det er relevant for deg, altså hvordan det kan brukes og så videre?
H: Altså om jeg lurer på det eller om jeg tenker at det kan brukes til…?
Int: Ja, begge deler.
H: Jeg burde kanskje tenke mer over det, for da kan det ofte gi litt mer mening og forstå flere sammenhenger og sånt. Men nei, jeg pleier ikke å tenke over det.
Int: Ehm, ja. Det var vel det jeg ville si nå innledningsvis. Og da går vi videre til Gjertrud, hvorfor har du valgt R1?
G: Jeg synes matte er veldig gøy.
Int: Ja!
G: og så er det veldig gøy at når du får til en oppgave så er det et fasitsvar. Det er ikke tonnevis med sider om "det kan jo være", "det kan være dette"; det er deilig.
Int: Ja, sånn er det.
G: Ja.
Int: Ehm, noe annet du vil si, eller?
G: Nei, jeg synes det er gøy:
Int: har du noen spesielle ønsker, ambisjoner for videre utdanning og karriere?
G: ehm, **jeg tror det blir noe innenfor realfag. Eh, biologi eller sånn… men jeg har veldig lyst til å gjøre psykologifag også, jeg synes alt er veldig gøy så jeg klarer ikke å bestemme meg.**
Int: Så dere er i samme båt i forhold til jeg vet ikke helt…
G: Ja
Int: Du har litt peiling, litt retning…
G: Ja
Int: Det er litt interessant at du trekker frem akkurat biologi og psykologi…for det er jo….kan du si
G: Ja

Int: Biologi er…
G: det er veldig viktig faktisk
Int: nettopp
H: [laughs]
G: Det der tenke…
Int: Og det finnes jo faktisk et fag som heter biologisk psykologi
G: Gjør det? Hæ?
Int: Ja, de som studerer for eksempel hvordan hjernen henger sammen…
G: Å, hvorfor har jeg aldri hørt om dette før
Int: …hvordan hormoner, studerer… det kalles endokrinologi, ett fag…
G: åj!
Int: altså det er hvordan… hvordan hormoner virker… hvordan det påvirker kroppen
G: Så gøy!
Int: Så det… Ja! Det finnes en mellomting!
G: Åj! Dette må jeg finne ut av …
Int: [Laughs] Det må du, det må du…
Int: Ja!
Int&H: [Laughs]
Int: Så, har du noen tanker ….den matten du lærer her av kjetil… og resten av verden…
G: Ja, altså… loga… **jeg føler egentlig at det vi lærer er sånn videre til at vi kan lære noe vi kan få bruk for…**
Int: mhm
G: egentlig… akkurat sånn når du lærte gangetabellen, hvorfor må vi lære gangetabellen, nå bruker jeg gangetabellen hele tiden.
Int: Ja
G: Så eller… lære å telle liksom…. Så jeg føler det er et steg til å kunne gjøre noe
Int: Ja
G: så for eksempel vi bruker jo logaritmer i kjempemye men ikke sånn som vi gjør, sånn videre i logaritmer
Int: Ja. Bare holde litt på det du sier der… har du noen eksempler? Hva…
G: Man bruker logaritmer for eksempel i facebook… så har de
Int: javel?
G: så har de logaritmer som holder oppe hva ting… hva folk gjør… gjør de ikke det?
Int: Jeg vet ikke jeg bruker ikke facebook?
G: Pappa sier… gjør du ikke?
Int: Er det algoritmer du tenker på?
G: algoritmer! Det gir mer mening…
Int: En algoritme er en prosedyre, en steg for steg metode som datamaskiner bruker…
G: Ja, ja…
Int: og så en logaritme er det motsatte av en eksponentialfunksjon som vi bruker i matematikken
G: Ja, da tenker jeg bare at…
Int: Ja det er helt i orden… det er veldig like ord. Til og med min mor lurte på hvorfor jeg skulle lage en film om algoritmer….Så det… det går greit
Int: ja, utover det da…
G: nei, ikke så tenkt så mye utover det…
Int: Nei nei.. Spurte jeg deg om det i sted, Hilde?
H: ..
Int: Ja, jeg glemte det… Ok, så har dere nylig lært om logaritmer. Rett før vinterferien hvis jeg forstod det riktig.
G: ja
Int: ok det har jeg sagt… Da ser vi filmen.
(6:15)[viser filmen]
[ferdig] (11:01)
G: Hva betyr et reelt tall?
Int: Det er alle tallene vi jobber med til vanlig. Har du hørt om imaginære tall?
G: Ja
Int: Det er alle tall som ikke er imaginære
G: å, ja!
Int: Så en, to tusen, pi, minus tusen, million, alt sammen, det er reelle tall.
G: Ok, ja
Int: Så det siste jeg sier der er at … tenker de reelle tallene kan vi sette opp på en tallinje…

G: Mhm
Int: ikke sant, vi har null et sted… så har vi negative, og positive…
G: Mhm
Int: Og de tallene som er mellom null og oppover, og de som er på hele linja, er like mange. Det er like mange fra null og oppover som på hele linja.
G: Hvorfor det?
Int: Det har jeg ikke tid til å forklare…
G: Nei ok.
Int: Men. Sånn er det. Det kan vise ved hjelp av en logaritme
G: ok. Det gikk ikke mening
Int: Helt meningsløst, helt merkelig, men sånn er det.
H: Det gir faktisk ingen mening
Int: Det gir mening, men ikke når du hører det sånn som dette.
H: Nei
Int [laughs] Umiddelbare tanker om filmen?
G: Ehh.. **det var godt forklart. Men jeg tror jeg trenger mer fagkunnskap for å kunne… for eksempel sånn… jeg visste ikke hva det var.**
Int: Ja
G: Kunne litt mer ord.
Int: Det er fint innspill. Hilde?
H: Det var jo bra, men jeg forstår ikke så mye… om logaritmer, skjønner jeg…. Det er liksom, noen ganger måtte jeg tenke litt ekstra. Det kan jo gi en pekepinn hva logaritmer faktisk kan brukes til…
Int: Ja
H: Bare det at du nevner alle fagene, det gjør jo sånn at "oi"… det gjør meg oppmerksom på at det kommer i mange retninger…
Int: Ja. Kunne du ønsker deg at det var mer… forklaring på hva som er logaritmen her?
H: jaa.. ehh…
Int: For eksempel på disse tallinjene da…
H: Ja
Int: Ja, riktig. Men da noterer jeg meg det. Bare for å se det veldig kort da, her ser du at avstanden fra null til 5, fem til ti, ti til femten, femten til tjue også videre
H: Ja
Int: Men her ser du at avstanden fra en til ti… ja nå får du ikke sett hundre her… men det er den samme avstanden som fra ti til hundre. Hvis vi bytter ut disse tallene med logaritmen til disse tallene; logaritmen til en er null, til ti er en, logaritmen til hundre er to… så det er faktisk logaritmen til disse tallene som er fordelt med like intervaller.
G: Ja, det gir faktisk veldig mening.
Int: Ja
H: [Laughs]
G: Ja, det kunne du bare nevnt, så ville de andre grafene du viste blitt mer forståelige.
H: mhm
Int: mhm
H: Fordi at sånn, når jeg tenker meg om så forstår jeg det jo egentlig.
Int: ja
H: Og akkurat den der tenkte jeg litt ekstra for å på en måte prøve å forstå det litt mer.
Int: Mhm
H: men bare det at man … at hvis du sier sånn.. få litt bekreftelse på at ja det er liksom logaritmen til en er null og så… det gir litt mer mening
Int: Ja. Er det noe annet som var kanskje litt vanskelig eller uklart?
H: Ja! Noen av bildene var litt uklare
Int: Det er helt sant. Det handler litt om utstyret jeg hadde tilgjengelig for å lage filmen.
H: Ja, akkurat det, der ja, du sa noe om åtte hundre. Er det fra X-aksen?
Int: Ja! Det er på y-aksen
H: Åja, nå ser jeg det!
Int: en, hundre… ti, hundre, tusen…
H: Ja
Int: Så ser du de små strekene der… det blir den første, to hundre, tre hundre, fire hundre…så blir det åtte hundre den treffer der
H: Ja, nå ser jeg det…

G: Hvorfor blir den første to hundre?
Int: … eh,… hund… ja…Det er jo hundre…
G: Ja
Int: Så den neste av de små strekene blir to hundre,
G: Ja
Int: en, to , tre…
G: Ja, ja
Int: syv, åtte, ni, så kommer tusen
G: Ja
Int: Så du kan si de små strekene mellom en og ti her, de viser en, to tre, fire, fem, seks, syv åtte, ni….
G: Ja
Int: Fra ti til hundre er det ti, tjue, tretti, førte, og så videre….
G: Åja, ok
Int: Og fra hundre til tusen er det hundrere
G: Åhh
Int: Og du ser de kommer mye tettere i toppen, og det er fordi dette er logaritmer. Hva tenker dere om den grafen der da, om spedbarnsdødelighet?
…
Int: Her kommer det frem at hvis barnet er mellom for eksempel mellom to og et halvt og fire og et halvt kilo cirka så er det veldig lav dødelighet …
H: Det er ikke overraskende
Int: … nei… og så kommer vi ned til ett kilo, så rett i taket
…
Int: Nå har vi snakket litt om kanskje noe sånn småting som kan vært endret på, tydeligere forklaringer kanskje … Er det noe dere savner i filmen, noe dere ville sett mer av eller lagt mer vekt på?
H: altså, først bare lurer på… er denne filmen, på en måte, det er for oss som lærer om logaritmer, det er ikke sånn at hvis jeg ikke kunne noenting så kunne jeg gått også lært litt av den?
Int: Nei. Meningen er at du skal ha lært om logaritmer i klasserommet, og så skal denne her forklare hvorfor vi lærer om logaritmer
H: Mhm. Ja. Fordi at … hvis jeg bare tenker at dette er et tema jeg kan lite om, så kunne jeg fort kanskje gått inn på youtube og sett, for å finne noe som forklarer det bedre. Og hvis jeg kommer over noe sånt så ville det vært helt topp tenker jeg. Men bare … de aller letteste forklaringer om … du sier noe om den naturlige logaritme inne i videoen,
Int: Ja
H: bare liksom en ekstra sånn derre …huske… den naturlige logaritme det er dette … bare en sånn ekstra påminnelse…
Int: Ja
H: Men det er mange som husker det sikkert, men
G: Ja, men det synes jeg også er veldig smart.
At du bare får liksom
H: kort forklart, hva er en logaritme
Int: Mhm
H: Det trenger ikke være mer enn en setning
Int: Mhm. Det noterer jeg meg. Noen andre tanker?
…
Int: nei.
H: Nei
Int: Nei. Er det noen av de tingene jeg tar opp her som dere kan relatere dere til personlig? …I forhold til det jeg nevner om medisin, økonomi, demografi….eller noen av de eksemplene på fagområder hvor logaritmer brukes?
G: Ja, jeg synes at da du nevnte fagområdene … så er det sånn… **jeg kan bruke det i biologi, og… og psykologi ble jeg litt sånn… hva er det… sosiologi ja…så ble jeg sånn "åja, kan du bruke det der også", men så skjønner jeg jo når du har nevnt det, at det går jo an å bruke det, du har jo masse grafer og… vet ikke. Men… bare, vet ikke, kan relatere det siden jeg skal velge nå… Det er fint å vite at matten har noe å si**
Int: Nei
H: Det føles ikke alltid sånn…
Int: Nei, jeg tror det er et vanlig problem akkurat det der.
H: Ja
Int: At en lurer på hvorfor i all verden vi holder på med dette her

H: Spesielt i sånn teoretisk matte. Og… tung matte på en måte, i forhold til praktisk matte. Det virker i hvert fall som de har sånn "sånn er dette og dette brukes det til". Men det er nesten sånn at jeg synes lærere burde si litt oftere, dette kan brukes til dette. For det hjelper oss mye mer i hva vi…hvis jeg synes logaritmer er veldig vanskelig så kan det være en pekepinn for at jeg bør velge noe annet enn kjemi… nå er det jo sånn videre… jeg vet ikke hvordan jeg skal forklare det… men hele kjemidelen er jo ikke logaritmer, men for eksempel det med pH og sånt er jo logaritmisk skala… men bare sånn at jeg vet litt mer hva som inneholder det temaet som vi holder på med… ga det mening? [laughs]
Int: Ja jeg synes det… så det kan være nesten en advarsel… "her brukes det logaritmer"?
H: Ikke alltid advarsel…
G: heller mer sånn det er faktisk en grunn til at dere gjør dette her… du sitter ikke her fordi jeg ikke liker dere liksom….
Int: mhm mhm ja
H: Det er også en måte å si det på
All: laughs
Int: Tror dere denne typen filmer, så ikke ser på det tekniske, det regnetekniske i det hele tatt men kun ser på bruksområder, at det kan være motiverende?
G: Hvis det hadde vært en sånnen for hver del av kapitler, at læreren satt den opp når vi begynte, sånn Her har dere grunnen til at vi lærer om dette temaet, sånn, da får du litt motivasjon "åja, ok, dette er nyttig, kan vi bruke".
Int: ja
G: Det hadde vært greit
H: veldig enig
Int: Ja. Så dere synes dette kunne vært en del av undervisningen, denne typen filmer?
G&H Ja absolutt
H: Det tror jeg kunne vært litt viktig og.
G: Ja, hadde vært deilig
Int: Noen avsluttende tanker helt til slutt?
H&G: Nei
Int: Nei, nei. Men tusen takk, veldig mye nyttig dere har sagt. Gode tilbakemeldinger Da må jeg bare takke for det. Ja, dere har vel ti minutter igjen av timen… Ja, takk! Ha det bra!
G&H: Ha det fint!