TAMPERE UNIVERSITY OF TECHNOLOGY

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Educational Videos and the Use of Tools in Mathematics Remedial Instruction

Master of Science Thesis

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Tekniikan alan kasvava työtarve on pakottanut yliopistot kasvattamaan opiskelijoiden sisäänottoa. Kaikkien opiskelijoiden lähtötaso ei kuitenkaan ole riittävä yliopisto-opintoihin, joten yliopisto-opiskelijoiden keskeytysprosentit ovat kasvaneet. Tampereen teknillisessä yliopistossa opiskelijoiden matematiikan taitoja parantamaan on kehitetty matematiikkajumppa, jonka kehitystä tämä diplomityö tutkii.

Tämä tutkimus on osa Matematiikan laitoksen opetuksen kehittämisen tutkimusta, ja sen lähtökohtana ovat syksyllä 2015 opintonsa aloittaneet opiskelijat kursseilla Insinöörimatematiikka 1 ja Matematiikka 1. Opiskelijoille järjestettiin syksyn alussa matematiikan perustaitotesti, jonka tarkoituksena on testata lukion matematiikan osaamista. Testissä huonosti menestyneet opiskelijat ohjattiin matematiikkajumppaan. Tässä diplomityössä kehitettiin matematiikkajumppaa tutkimalla oppimistyökalujen, erityisesti opetusvideoiden, luomista, käyttöä ja tehokkuutta. Pedagogisina viitekehyksinä toimivat Mayerin, Gagnén sekä Bloomin teoriat.

Matematiikkajumppa toteutettiin Math-Bridge -ohjelmistolla, ja jumppaan liitettiin Echo360 -alustalla toimivat opetusvideot jumpan aiheista. Opetusvideoiden käyttöä mitattiin niin empiirisesti havainnoiden kuin myös jumppaa koskevan kyselyn avulla. Tämän lisäksi opiskelijoiden perustaitotestit, oppimisprofiilit ja tenttiarvosanat Insinöörimatematiikka 1 ja Matematiikka 1 -kursseilta kerättiin, ja niiden avulla selvitettiin, miten matematiikkajumppaa tulisi kehittää jatkossa.

Työn lopputuloksina esitellään viitekehys opetusvideoiden luomiselle, jota seuraamalla jokainen opettaja voi aloittaa videoiden käytön opetuksessaan. Tästä esimerkkinä esitellään tätä työtä varten tehdyt opetusvideot. Oppimistyökalujen käytön analysointi osoittaa, että opetusvideot ovat rikastava lisä matematiikan tukiopetukseen, ja että matematiikkajumppa on onnistunut tapa toteuttaa matematiikan tukiopetusta. Erilaisten oppimisprofiilien työkalujen käytön ja opintomenestyksen tarkastelun tuloksena oppimisprofiileista saatiin uutta tietoa, jonka perusteella työssä on esitelty kehitysideoita matematiikkajumppaan.

ABSTRACT

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The increasing workforce demand in the field of technology has forced universities to increase their student intake. However, for all students, their starting skill level is not high enough for university studies, which has increased drop-out rates. At Tampere University of Technology, a Remedial Instruction has been developed to improve students' skills in mathematics.

This thesis is a part of teaching development research at the TUT Department of Mathematics. It is based on the students starting their studies in fall 2015 on the courses Engineering Mathematics 1 and Mathematics 1. In the beginning of the fall, these students took the Basic Skills Test in mathematics, and those that did poorly were directed to the Remedial Instruction. In this thesis, the Remedial Instruction was developed further by studying students' use of tools and adding educational videos. Pedagogical framework was derived from works of Mayer, Gagné and Bloom.

The Remedial Instruction was deployed using Math-Bridge, and for the first time, educational videos on different mathematics topics were added using the Echo360 platform. The use of these videos were measured both empirically as well as with a questionaire about the instruction. In addition, the students' Basic Skills Tests, learner profiles and exam grades in (Engineering) Mathematics 1 were collected. This data was used to study how the Remedial Instruction should be developed in the future.

The results of this thesis include a framework for educational videos which can be used by teachers to apply videos to their teaching. As an example, the videos created for the Remedial Instruction are presented. Students' use of tools was analyzed and it shows that educational videos are an enriching addition to remedial mathematics, and that the Remedial Instruction is an effective tool in helping students learn mathematics. Analyzing the different learning profiles together with their use of tools and success in studies, new information was gained from the different learner profiles. Based on this, ideas for Remedial Instruction development are also presented.

FOREWORD

This thesis is a continuation to previous studies about university teaching and learning at TUT's Department of Mathematics. While writing this thesis, I have been very fortunate to be able to apply multiple skills that I have trained over the years, including but not limited to mathematics, teaching, the English language, video editing, pedagogy and research. I feel that I've grown as a professional while working on this thesis, so it is only fitting that it would stand as my final piece of work before graduation.

I would like to sincerely thank Professor Seppo Pohjolainen for supervising this thesis and for giving me the opportunity to work with him in developing teaching at TUT. Prof. Pohjolainen's trust in me has led to a fruitful collaboration in which I've always felt as the more receiving part. The opportunity to work full-time on this thesis has been invaluable to me. It is important that I also thank the two people that have had a great impact on my choice of career: Mr. Risto Silvennoinen for giving me my first job at the university, and Mr. Lasse Vehmanen for crushing my insecurity in mathematics. I want to also thank Mr. Simo Ali-Löytty for helping me finish this thesis and acting as a second supervisor.

TUT's Department of Mathematics has been an excellent place for me to grow as a professional and as an individual. I want to thank my co-workers Jukka-Pekka, Jussi, Lassi, Heikki, Kari and everyone else for a great environment, all the support and all the discussions and laughs we have shared.

This thesis is the culmination of a story that started seven and a half years ago. Little did I know, that during this time I would have forged friendships that will last a lifetime. I want to thank Pinja, Arto, Ville, Niko, Joonas-Juho, Pekko, Iivu, Eeli, Maija, Aino, Kalle, Matias, Junnu, Vesa, Paavo, Jukka-Pekka, Eero, Mike and Sami for all the great times spent together. Also, thank you to everyone in the TUT student community. Your names are too numerous to list on this page, but you have all been important on this journey.

Last, I want to thank my family. I have always been able to rely on their love and support. Thank you to my father Mikko, mother Liisa and brothers Jussi and Matti. None of this would have been possible without you.

Tampere, 3rd of February 2016

Tuomas Myllykoski

CONTENTS

LIST OF ANNOTATIONS AND ABBREVIATIONS

f	Frequency
$f\%$	Percentage value of frequency
n	Sample size
$SE_{\bar{x}}$	Standard error of the mean
s	Standard deviation
s^2	Variance
x, y	Variables
x_i	Factor's observed value
$\bar{x}$	Sample mean
r_{xy}	Correlation coefficient for x and y
s_{xy}	Covariance between x and y
t	t-test value

ADDIE	Analyse, Design, Develop, Implement, Evaluate
BST	Basic Skills Test (in mathematics)
RI	Remedial Instruction
CAS	Computer algebra system
FEV	Framework for Educational Videos
ICT	Information and communications technology
ITS	Intelligent Tutoring System
PCK	Pedagogical Content Knowledge
Q&A	Questions and answers
STACK	System for Teaching and Assessment using a Computer algebra Kernel
TUT	Tampere University of Technology
VCR	Videocassette recorder

S.O.L.	Surface oriented learners
Peer L.	Peer learners
S.N.S.	Students needing support
Ind. L.	Independent learners
Skill. St.	Skillful students

1. INTRODUCTION

The field of technology depends on the modern school system's ability to educate skillful engineers and masters of science to work in highly skillful positions across varying fields of expertise. The constantly growing need for capable engineers has lead to an increase in student intake at technical universities across Finland. However, not all students that are accepted into the universities are equipped with sufficient skills in mathematics to succeed in their studies. This has lead to increasing drop-out rates of young adults, which has severe effects on personal and national well being. This is not a problem that is only apparent in Finland, but rather, a global problem.

One of the universities that has had to increase student intake is Tampere University of Technology (TUT). The local Department of Mathematics has put significant efforts to reducing the drop-out rates of students, and has been quite successful at it. The department tests students at the start of their studies using a Basic Skills Test (BST) in order to determine the students' starting level. For students that do not do well in the test, additional remedial mathematics are ordered in the form of a mandatory Remedial Instruction. The enhancement of this Remedial Instruction using mathematics videos, as well as a study on students' use of different learning tools, is the topic of this thesis. Previous studies by the Department of Mathematics have been about student attitudes, motivation and orientation in mathematics as well as log data based activities in the Remedial Instruction. [13, 26, 20]

This thesis uses the data of the BST and Remedial Insruction of fall 2015. Also, educational videos were recorded, edited and published to be used by students during the Remedial Instruction. Analysis on student activity in the Remedial Instruction was done based on empirical observations as well as students' answers to a questionaire about their Remedial Instruction experience.

The aim of this thesis is to examine if educational videos could serve a role in TUT's remedial mathematics, and to provide know-how for teachers in how to take multimedia into use in their teaching. Also, student activity with different tools during remedial mathematics is studied. Also, based on the findings of this thesis, the most important and efficient courses of action regarding the future of the Remedial Instruction are presented.

2. PROBLEM-SETTING AND THEORETICAL BACKGROUND

In the modern world, technology is closer to us than ever before. The revolution of mobile technology, alongside the development of computers, has led to a situation where everyday life includes the new inventions these breakthroughs have brought with them. The rise of the internet in the 90's and early 00's, combined with the high processing speed of even the layman's computer, have brought us inventive new ways to do the things we previously did by hand.

One of the most important aspects of everyday life is education. Inside education, and especially engineering education, one of its most prominent subjects is mathematics. Needless to say, mathematics has not remained untouched by advances in technology, and has actually been one of the forefronts where technology has first been applied to teaching [6]. This has created an ever shifting, constant demand for new and more efficient technological solutions, which has later spawned its own field of research. When talking about mathematical education research, one will often be unable to dodge such terms as "modern learning technology", "technologically enhanced learning", "e-learning" or "instrumentation". It is safe to say that in the future, the integration process of technology and mathematics will continue.

However, even when moving forward with e-learning, it is important to keep in mind that students and their opinions are very important. As brought forward by Alexandre Borovik in 2010: "Students prefer a choice in how they learn - ICT is seen as one of many possibilities, alongside part-time and traditional full-time learning, and face-to-face teaching [5, 19]." Borovik also notes that "Students could see some advantages to an e-learning approach. If it were presented as an option, as opposed to an obligation, it would avoid onerous undertones." When considering technology, it is also important to note that content matters for students more than delivery.

This chapter aims to present the theoretical background of supportive mathematics teaching at Tampere University of Technology. It also delves into the methods used to battle the *mathematics problem* [12] at TUT, and gives more depth to the tools, which are used in this thesis to further enhance the supportive teaching methods at the university.

2.1 Math-Bridge

In 2009, the European Comission's Information Society's eContentplus program started project Math-Bridge - its aim was to provide multi-lingual and multi-cultural semantic access to remedial mathematics content, which adapt to the requirements of a learner and the subject of study. After its completion in spring 2012, Math-Bridge has been seen as a tool to be used in bridging the gap between secondary school and university mathematics. The final outcome of the project was the online learning platform Math-Bridge. [8]

One of the main objectives of the project was to collect study material all around Europe and to combine them under a single platform. The study material was divided into several learning objects, each with their own class and hierarchy in the system. This way, a more personalized way of teaching was made available to teachers. Math-Bridge uses an Intelligent Tutoring System (ITS) called ActiveMath as the basis for the learning platform. ActiveMath takes student progress into consideration, and is able to offer him or her progressively more difficult tasks based on their current knowledge level. [3, 23]

The different learning objects inside Math-Bridge can be combined into electronic books - a combination of theoretical material and mathematical problems, each piece with a place in the original source material, and all interlinked with each other through the hierarchy trees in the system. All of the material inside Math-Bridge has been translated into seven different languages: English, German, Finnish, Dutch, French, Spanish and Hungarian. This enables students to study mathematics not only all across Europe, but in a foreign language as well.

After the end of project Math-Bridge, the online learning platform has enjoyed a steady use across Europe. At Tampere University of Technology, Math-Bridge is used in the Remedial Instruction, which shall be discussed in a later section. The future of the system is also looking bright, as two new projects are ongoing that are planning to use Math-Bridge: MetaMath and MathGeAr [24, 25]. Using Math-Bridge in these projects would also include expanding the language base of the platform, as new languages would include Georgian, Armenian and Russian.

2.2 The Basic Skills Test and Remedial Instruction

Since 2002, a starting level test titled Mathematics Basic Skills Test has been organized at Tampere University of Technology. The test is intended for first year students, and it should be taken immediately after entering the university and thus it is a mandatory part of completing the first mathematics course at the university, Engineering Mathematics 1 or Mathematics 1. The test consists of 16 questions from varying topics in Finnish high school mathematics. The test is done using computers, and the software tool used is STACK (System for Teaching and Assessment using a Computer algebra Kernel [22]), which automatically evaluates the students' answers. Each question in the test is worth one point, and those who do not score enough points in the test are directed to the Mathematics Remedial Instruction. In 2014, the limit was seven points in Engineering Mathematics 1, and nine points for Mathematics 1. Due to the fact that the test is completely automatized, it does not add to the work burden of teachers, and is quite cheap to organize.

The Mathematics Remedial Instruction is, as previously mentioned, intended for students that do not demonstrate sufficient knowledge in the Basic Skills Test and are thus in danger of having serious problems in the first year mathematics courses. The instruction is designed to work as a means to brush up high school mathematics at a personal pace, and it is also available to those students that passed the Basic Skills Test. If they never even completed the Basic Skills Test, the Remedial Instruction will compensate it. The instruction consists of 71 mathematics problems, which must all be completed correctly in order to complete the Remedial Instruction. The problems are simple exercises from the high school level, and there are ten different categories:

Differentiation: Nine differentiation tasks in which the student must differentiate polynomials, trigonometric functions, composite functions and logarithms.

Equations: Seven tasks of equation solving that include solving first, second and third degree equations, as well as absolute value, square root and fraction equations.

Expressions: Six tasks of calculating values of given functions and composite functions, simplifying basic and fractional expressions, and defining inverse functions.

Inequalities: Seven inequality tasks, designed to go over solving first and second degree inequalities, as well as absolute value and fractional inequalities and their combinations.

Integration: Eight tasks of integration. Solving polynomials, exponential and absolute value integrals and definite integrals.

Limits: Six limit tasks in which students define the limits of polynomials, fractional expressions, trigonometric functions, constants and piecewise functions.

Logarithms: Seven logarithm tasks that delve into exponential equations and logarithm equations and inequalities with different base numbers.

Numbers: Seven tasks that teach the concepts of inverse, complement and absolute value. In addition, some tasks focus on calculating values for expressions with given parameters.

Powers: Seven tasks of solving expression values when using powers and roots.

Trigonometry: Seven tasks about trigonometry consisting of degrees, radians and of trigonometric functions that use sine, cosine and tangent.

The Remedial Instruction is done using Math-Bridge. In Figure 2.1, a student view of Math-Bridge is shown. The 71 mathematical tasks are listed under "Remedial Exercises", and these tasks are also available in a more book-type setting under "Mathematics Remedial Instruction", in which the problems have been inserted between learning material objects. Students are free to choose between the view with only the problems, and the more book-like approach.

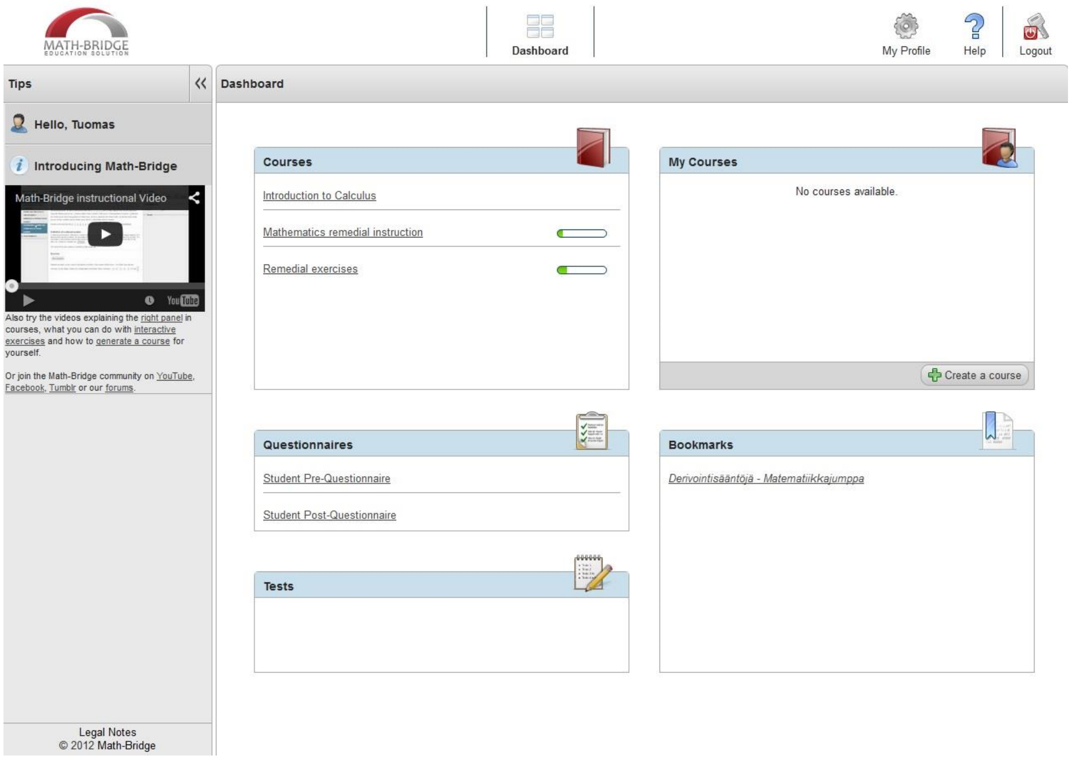

Figure 2.1: The view for Math-Bridge for a student who has logged in.

The book view is shown in Figure 2.2. On the left the student has all the chapters of the remedial instruction, in the middle the book itself is shown with examples, learning material and interactive STACK exercises. Opening one of these exercises will lead the student to a view similar to the one in Figure 2.3. In TUT's Remedial Instruction, Math-Bridge calls STACK to generate new randomized parameters for the exercise. This way the assignment is a little bit different every time it is opened.

The exercises consist of the assignment itself, and under it a text field is given. Here the student is supposed to type their answer. After the input they check their answer's syntax, and if they are not happy with it, the syntax can be modified.

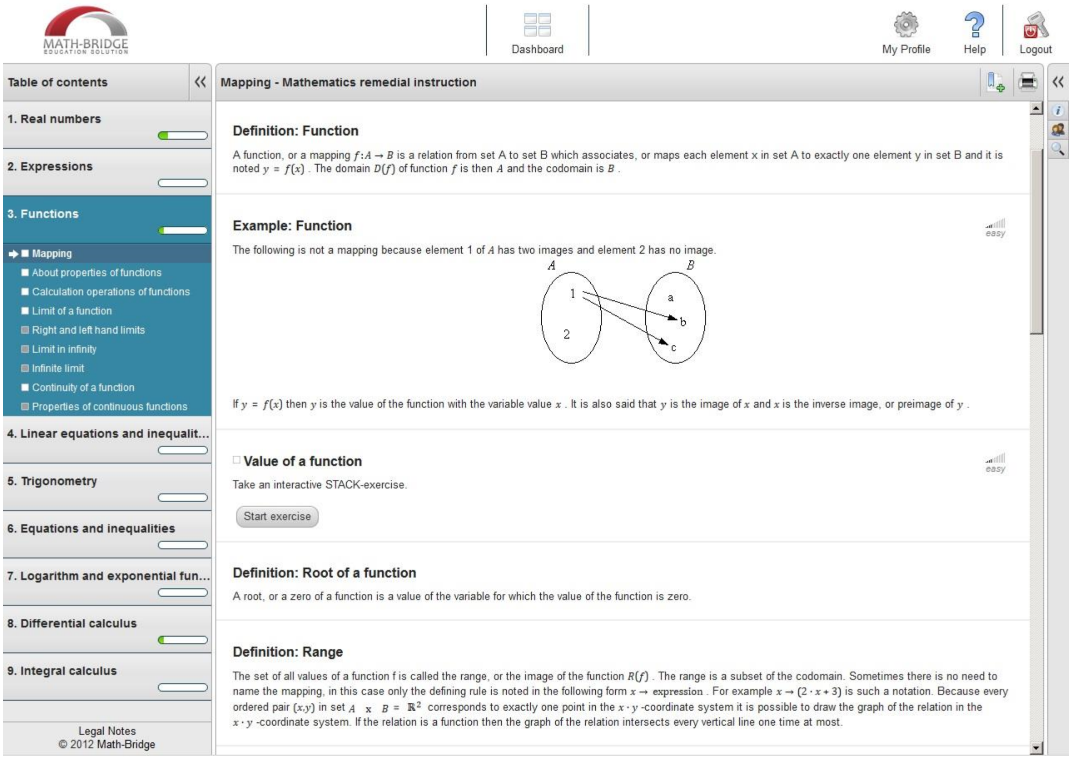

Figure 2.2: The view for the Remedial Instruction course book.

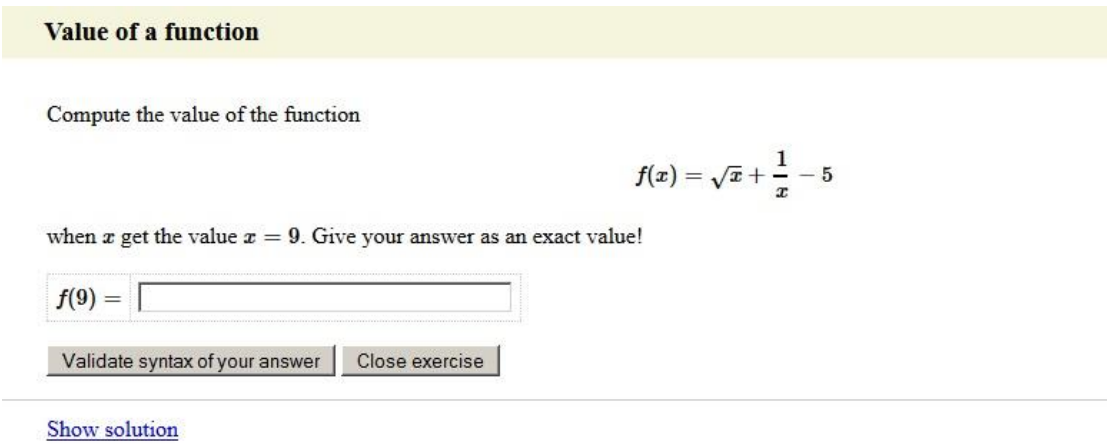

Figure 2.3: The exercise: an assignment, an answer field, a validate syntax button and a hyperlink that shows the solution.

Math-Bridge will provide immediate feedback after the answer has been submitted. It is possible for the teacher to modify the answer tree of the exercises so that the exercise can be done in parts, and each step can have its own feedback. If the student finds the task too difficult, they can consult the solution using the hyperlink below the assignment.

2.3 Enhancement of the Remedial Instruction

When considering the need for enhancements in the Remedial Instruction, one particular topic was pointed out above others: the study material is available, but it is often overlooked. Reasons for this might include the student's lack of understanding of the material, the fact that this particular material has never been covered by their own teacher, or the fact that the material might simply be too complex for a Finnish high school graduate to understand. Here is an example of a definition found under *Linear equations and inequalities:*

Definition 2.3.1 (Simplifying a linear equation with multiple variables)**.** A two variable linear equation can be simplified to the form

$$a \cdot x + b \cdot y = c,$$

where $a, b, c \in \mathbb{R}$. The domain of a two variable linear equation is the product set $A \times B$. Similar three variable equation is defined in the set $A \times B$. Generalization for other linear equation domains is obvious. The solution set of a linear equation is a subset of its domain. For example in the case of a two variable linear equation the solution set consists of pairs (x,y) which satisfy that equation. △

The definition above is an example of explaining things in an unnecessarily complex manner, and it is quite useless at helping a young engineering student to be inspired of mathematics, or to see the added value that this mathematical construct can bring to his knowledge pool. This is true for some other material in the Remedial Instruction as well, and thus the need for enhancement became apparent.

The main suggestion of enhancement has been the creation of simple educational videos that would help to bring the mathematical theory and the examples closer to the student. It was decided that the videos would be created for those exercises that were deemed most difficult in Venho's master thesis in 2013 [26]. These exercise were

- Calculate the derivative of the sum of multiple trigonometric functions, example:
$$f(x) = 6\cos(9x) + 5\cos^9(6x) + 7\sin^3(5x) + 5\sin(5x),$$
- Calculate the derivative of a fractal expression inside a logarithm, example:
$$f(x) = \ln\left(\frac{x-8}{x^2+6}\right),$$

- Calculate the derivative of an exponential function multiplied by a logarithm to a fractal power

$$f(x) = e^{-\frac{1}{4}x}(\ln(9x))^{\frac{1}{3}},$$

- Solve a rational inequation of the form

$$\frac{7x}{5} < \frac{1-5x}{x-7},$$

- Solve an absolute value and fraction inequality of the form

$$\left|\frac{3x+1}{7x-1} - \frac{3}{7}\right| < 21,$$

- Integrate a simple polynomial, such as

$$\int_{-5}^{2} 2x^4 - 2x^2 - 3 \; \mathrm{d}x, \text{ and}$$

- Integrate an absolute value expression of the form

$$\int_{-3}^{2} -3|x^2 + x| \; \mathrm{d}x.$$

Looking at this list of difficult topics, a plan for the videos can be constructed quite easily. The main topics that should be covered in the videos include at least the following: derivation, the chain rule, fractals, inequalities, absolute values and integrals. It is also important to note that the videos are simply another tool to be used by the students. As noted previously, students enjoy having multiple tools to choose from. Constructing quality videos requires skillful use of pedagogy and didactics which will be discussed in the next chapter.

2.4 The ADDIE model

When implementing new e-learning tools such as educational videos, the ADDIE model can serve great quality instruction and checkpoints for the creator [2]. The five steps of ADDIE are:

- ANALYSE (10 % of budget)

  Developing learner profiles, identifying learning spaces & devices, researching learning resources and determining delivery & assessment strategies.

- DESIGN (36 % of budget)

Storyboard the design, plan and test using prototypes, identifying network capacities, designing online learning spaces, exploring and refining technology options and considering using repositories.

- DEVELOP (35 % of budget)

  Deciding on Insourcing/outsourcing, conducting testing, ensuring that security, backup & access requirements are met, confirming licensing, copyright and accessibility.

- IMPLEMENT (4 % of budget)

  Providing tools for learners, conducting delivery and assessment, providing entry points for the learners and preparing teachers for e-learning.

- EVALUATE (7 % of budget)

  Sharing results and collecting, interpreting and understanding data.

As can be seen above, the ADDIE model is a great tool for expanding on the Math-Bridge experience. Going through the different parts of multimedia creation according to ADDIE is quite simple to do at TUT due to the fact that most aspects are already in place due to previous studies and projects.

Analysing in the Remedial Instruction is one part of this thesis. Learner profiles (next section) have already been studied before, and in this thesis, there is an aim to find out what kinds of tools are used by students during the Remedial Instruction. This includes learning spaces, devices and resources. It is also to important to test the deployment of the mathematics videos. Several platforms are available, and out of those, the Echo360 platform will be used.

Design of educational videos is one of the most important results of this thesis. This thesis aims at creating a Framework for Educational Videos (FEV). This way, the design part of ADDIE will be presented in the later chapters. Also, the results of the framework creation can be compared with the ADDIE model. Online learning environments are already in place due to Math-Bridge, and STACK is the already explored technology option. Technology options for the videos will also be discussed later.

In the development stage, the videos were constructed completely in-house. Thus there was no need for outsourcing. However, the Echo360 platform (discussed later) is an external program used by TUT. Testing was conducted before launching the videos for public use. The videos were published to YouTube for everyone to use.

Implementation has been done using Math-Bridge, as the videos are be hyperlinked to the system, and are available to students trough the Echo360 platform. Assessment was done by Math-Bridge, and students had easy access to the material due to its remedial nature. Finally, the results of the videos are presented in Chapter 4, which also contains the collected, interpreted and analyzed data. Clearly, the ADDIE model is an excellent tool for creating and modernizing e-learning tools. Different aspects of the ADDIE model will be discussed later in this thesis.

2.5 Learner Profiles at TUT

In 2006, using cluster analysis, Pohjolainen et al. [13, 20] were able to divide all engineering mathematics students at TUT into five different categories. The design of learner profiles has been an important step in analyzing the different types of learning activities that students engage in, and provide excellent grounds for further analysis. Today, students are divided into these five categories in the beginning of the Basic Skills Test by having them choose from the following, which of these claims best describes their study habits and motivation in mathematics:

Surface oriented learners: My interests in mathematics are based more on my engineering study program rather than my own personal interests. I often calculate a given problem in the same way as was done in a book or in a class, and I rarely try to come up with my own way of solving it. I am capable of learning mathematics by copying solutions as long as I keep my mind in the process.

Peer learners: I enjoy studying mathematics together with other students and when doing exercises, I hope to get help if I am not able to solve a problem on my own. I focus on examples, and I feel that learning mathematics is necessary. When solving problems, I feel that arriving at the correct solution is important, even if mistakes were made. I enjoy being rewarded for my efforts.

Students needing support: When studying mathematics, I want to be personally guided in difficult parts of problems. The examples and teaching method of my teacher heavily affect the way I adopt the taught material. I'd rather already know how to solve a given task rather than to adopt and apply a previous solution. I often leave difficult problems out all together, or stop in the middle. The "language" of mathematics seems difficult to me.

Independent learners: I can learn mathematics if I feel that I need it. I'd rather not solve problems with my friends, but rather learn by myself. I also don't need a teacher to support me. Copying solutions does nothing for my learning experience.

Skillful students: I want to learn mathematics in a deep and fundamental way, and not by rote. When solving a difficult problem I do not give up easily, and try to solve it. I think I do well in mathematics.

Next a more detailed description of the different learner profiles is given according to [13, 20]. The first group is *surface oriented learners*, in which the uncertainty about students' own knowledge and skill is emphasized. These students do not possess the optimal attitude for studying, and thus their learning is shallow and superficial. These students are able to solve problems if they have an example from which to seek help. Even if these students spend time on their studies, they are often left without deep understanding of the studied topic. Memorizing different models isn't eventually any less burdening than striving for a deeper understanding without memorizing.

Peer learners find that the community in which they learn is very important, and their overall attitude towards learning is positive. The best results in learning are achieved when one of their friends can show them an example hands on. In addition, if a teacher takes note of their efforts, they tend to be inspired to continue studying. For these students, the learning experience is heavily influenced by their social circle in which they study: a good group can bring forth fruitful and concentrated discussion about the topic, therefore creating a deeper understanding of the subject at hand. At worst, the group will copy each others answers and later adopt very little of the studied material.

Mathematical skills are the weakest for *students needing support*. Their view of their own knowledge and skills, as well as their attitude, is significantly worse than for the other groups. They give up easily and lean on learning by rote, something that does not belong in university mathematics. Usually, when completing a task, they consider something half finished to be complete, and therefore their skills in self-assessment are also weaker. The language of mathematics poses a problem for these students. Students in this group often regard success as something independent of themselves, and they often wish that someone would help them hands on. Gaining positive experiences from this premise is difficult to say the least.

Independent learners have a good and healthy self-confidence regarding their studies. They feel at ease when solving problems and rarely rely on model solutions, their teacher or peer students when doing mathematics. The relevance of the latter is even less evident than for other learner types. The group has a good chance to adopt knowledge in way that best suits themselves and their learning strategies, and afterwards build and deepen their understanding even further. As a premise, web-based self study materials such as Math-Bridge are well suited for students in this category.

Skillful students do not give up easily when solving mathematical problems. They have a solid grasp of their own know-how and find that they are able to do mathematics. Their attitude towards mathematics is positive and they are more interested in the meanings inside mathematics rather than only the solutions of problems which they encounter. Unlike students needing support, skillful students acknowledge that their development in mathematics rests upon themselves. One good way for these kinds of students to learn is using logical deduction and taking responsibility for their own studies. This kind of motivation and a willingness to learn will usually produce good results.

2.6 Comparing Learner Profiles: SUAS Case

Other studies have also tried to divide students into different categories based on a proficiency test and their past success in mathematics. One of these studies was done by Porras [21], in which the skills of Saimaa University of Applied Sciences students were studied. The study aimed to solve the problem of teachers not knowing their students' starting skills besides their former grades. Thus the profiles created were based more on previous education and a proficiency test rather than mere psychological factors. The study notes "that freshmen may not even know their studying habits in an academic freedom due to lack of experience".

In the study by Porras 60% of student grades could be explained by the determined student type. All students at risk could be recognized quite well, but some students that were actually average were marked as being at risk. However, considering the aim of any remedial or supportive programs in mathematics, this is by no means a disaster. The student profiles were constructed using the students' previous grades in mathematics, their result in the proficiency test, and their selection of the following descriptions:

1. I think mathematics [is] easy to me. I try to do all exercises given and I do not feel studying to be frustrating at all.
2. I prepare for exams well in time and I do not necessarily need any applied examples from my professional field during the math lessons.
3. I want to study mathematics as much as possible. I also try to adapt my studying to the course requirements.
4. I know my knowledge in mathematics is not very strong. I consult my formula book as much as possible, although, understanding the formulas is not easy for me at all.
5. I know that I should do home exercises in order to learn.
6. I am not quite sure that this is the right place for me, and I'm not very interested in mathematics either. I should do a lot of work to pass the courses, but I will probably not be attending the lectures because I just do not feel like attending, or I have so much other activities.

7. None of the above describe me at all.

Students were asked to choose the profile that best described them, even if the description wasn't completely accurate. Students who chose profiles from 1 to 4 did well in their studies. Profile 5 usually referred to a weaker grade. If a student got weak results in their proficiency test and chose profiles 4 or 6, they were labeled as critical. This is interesting because if we compare profiles 4 and 6 with TUT profiles, we can see some similarities:

> *"I consult my formula book as much as possible, although, understanding the formulas is not easy for me at all."*

when compared to

> *" I'd rather already know how to solve a given task rather than to adopt and apply a previous solution.* ***The "language" of mathematics seems difficult to me."***

This shows us the connection between the students needing support and critical students. The quotes above are closely related to the SEFI competencies of handling mathematical symbols and formalism, as well as communicating in, with, and about mathematics [9]. This problem has also been the focus point of other studies at TUT, mainly following in the footsteps of Joutsenlahti and the concept of languaging as a tool of improving student results [14].

One should also note the problems in motivation as a critical part of poor success in mathematics. See for example the following:

> *"My interests in mathematics are based more on my engineering study program rather than my own personal interests."*

Now compare it to

> *"I am not quite sure that this is the right place for me, and I'm not very interested in mathematics either."*

Surface oriented learners might achieve good results, but they rarely possess any deep understanding of the mathematics that they are working with. Thus they are also running a risk of having problems in their studies - if not in the first courses, then perhaps later on as the difficulty level keeps ramping up.

The dialogue between these two types of learner profiles repeats the old and well known mantra: to learn mathematics, one must do mathematics. Also, studies have time and again shown, that motivation - preferably intrinsic - will serve any student well.

Summarizing the topics discussed before will reveal the following: the need for remedial mathematics is apparent in today's university world. Most of the students facing difficulties in mathematics either find the concepts, constructs and the language of mathematics difficult to follow, or they do not see the added value that mathematics can bring to their knowledge pool, and thus lack motivation. Now that the choice has been made to study tackling this problem using educational videos, a deeper understanding of this media is needed in order to fruitfully apply it to the problem at hand. How to help students better understand mathematical concepts, and how to fuel their motivation using videos? These topics will be discussed in the next sections.

2.7 Technology in Teaching and Learning

Using videos in education is definately not a new concept. Since the invention of television and the VCR, students all over the western world have been watching videos in classrooms. Films about biology, geography and nature have for many years served as a substitute for actually seeing for example the movement of tectonic plates, an erupting volcano, or the natural habitat of an endagered species. Solving rather simple mathematical problems has not been that well suited for this classroom size scale, but now, with the revolution of multimedia and portable computer devices, videos can be viewed almost anywhere. Thus it would serve us well to look into previous studies on the topic.

When talking about technology in general, it has been argued by Van B. Weigel in 2002 that technology has the potential to improve both quality and access ("richness" and "reach") of teaching [29]. According to Weigel, the level of engagement with which the learners engage content, as well as the number of students that get to engage the content, can be increased. Institutions often focus on the reach aspect of Internet, as it provides an easy and inexpensive platform on which to engage potential customers (or students in the case of an university), but Weigel argues that new technologies can also enhance the richness of the learning environment and "enrich and extend the students' exploration of new territory". This view is shared by the Department of Mathematics at TUT, and online learning has been actively pursued throughout the time of the technology's existence.

As noted by Muller in his PhD thesis *"Designing Effective Multimedia for Physics Education"* in 2008 [18], the amount of studies on multimedia is surprisingly small when compared to the fact that people have been using different multimedia in education for decades. According to Muller, it is actually quite startling that such a long use and research of educational technology has yielded so few productive outcomes. Muller identifies the main reasons for the lack of general and robust theoretical foundation for designing multimedia as the following: the self-evidentness of advantages of new technologies, the research questions being disconnected from theoretical considerations, the practical drive to introduce technology into schools moving too fast, and the ever changing fundamental view on how people learn.

The availability of certain technologies in classrooms almost instantly after their invention has led to some problems. Mainly these problems are associated with the outlandish promises by technology salesmen. A good example is the modern use of CAS calculators in Finnish high school mathematics classes. Very little studies were made before their implementation, and even less after! A book written by Guin et al. titled *"The Didactical Challenge of Symbolic Calculators"* [11] states the following: "Even if programs of study and official guidance make more and more frequent reference to tools, there is a clear lack of attention within the institution of schooling to conditions for their *viability*."

However, in 2015, A.W. (Tony) Bates published *Teaching in a digital age* [2], a modern view on guidelines for designing teaching and learning. This book straightforwardly addresses the strengths and weaknesses of video as a teaching medium. In it, the main strenghts of videos include linking concrete events and phenomena to abstract principles and vice versa; the ability of students to control the pace at which they learn; providing alternative study approaches for students; adding substance to any topic by linking it to the real world as well as their low cost today. According to Bates, the main weaknesses of videos in education are teachers' lack of experience; lack of high quality material openly available; time-consuming creation; requirement of specially designed activities outside the video itself in order to get most out of them and finally, "students often reject videos that require them to do analysis or interpretation; they often prefer direct instruction that focuses primarily on comprehension. Such students need to be trained to use video differently, which requires time to be devoted to developing such skills".

In order not to stumble in to the pitfalls discussed above, further study of using videos effectively is needed. As the topic is not that widely covered in the pedagogical field, common sense and personal experience will have to serve as a filler when required. Muller's PhD thesis is a good resource for ideas in using videos. The ADDIE model is an invaluable concept when designing and implementing any e-learning material. It would also serve us well to look into the success of the most widespread of all educational video platforms: Khan Academy.

2.7.1 Khan Academy

The most obvious first candidate to look at when talking about educational videos is Khan Academy [15]. Khan Academy is a non-profit educational organization created in 2006. It was created by Salman Khan, whose aim was to provide "a free, world-class education for anyone, anywhere". The organization producaes micro lectures in the form of YouTube videos, and these videos are massively popular, with the academy's YouTube account having 2,2 million subscribers (as of July 2015). In addition to micro lectures on YouTube, the organization's website features practice exercises and tools for educators. These resources are free for anyone around the world.

The technical format of Khan Academy is interesting in its simplicity: Drawings are made with a Wacom tablet and a natural drawing application SmoothDraw, and the screen is recorded using Camtasia Studio, a screen capture software. Khan himself does the voice over for the videos. An article by The Washington Post in 2011 titled "Web site offering free online math lessons catches on like wildfire" [28] emphasizes the fact that Khan Academy is in fact a tool for flipped classroom type of learning. Flipped classroom style of teaching will be discussed in a later section.

Khan's work has also been a subject to criticism. Pedagogists around the world have noted, that content knowledge alone is inadequate for quality instruction. Content knowledge is naturally very important for any teacher, and Khan demonstrates this. However, you would also need pedagogical content knowledge (PCK). PCK refers to knowledge of content as it relates to teaching. The reason this kind of knowledge is important for a teacher is critical for the Remedial Instruction: a teacher with strong PCK has a firm understanding of what kind of problems and misconceptions students might face when delving into mathematical topics. It has been noted that at some points Khan Academy videos have presented a clear lack of PCK. When making videos for the Remedial Instruction, PCK will be heavily considered.

To conclude, the way of teaching and implementing technology into education that Khan has made popular, is a pioneering move in the educational field. In this thesis, similar strategies will be implemented, and their effectiveness and usefulness will be studied. The concept of PCK is also important.

2.7.2 Mayer's Principles of Multimedia Design

In his thesis Muller discusses the works of Richard E. Mayer. Mayer has proposed a set of multimedia design principles, that has been established and empirically verified in his studies [16]. Mayer categorizes three kinds of cognitive processing during learning as the following: extraneous, essential and generative. These three are shown in Table 2.1.
These instructional goals attained through the study of cognitive processing are very essential for the design of educational videos. Mayer further outlines these instructional goals by separating each of them into principles, that help in achieving the given goal.

The following principles are intended to address the problem of extraneous over-

Table 2.1: Three kinds of cognitive processing during learning [16].

Cognitive processing	Description	Instructional goal
Extraneous	Not related to instructional goal, caused by poor instructional design	Reduce extraneous processing
Essential	Aimed at representing essential material, caused by complexity of material	Manage essential processing
Generative	Aimed at making sense of essential material, caused by learner's effort	Foster generative processing

load, which means students focusing on something else other than the topic that they are supposed to learn. The principles are:

- **Coherence principle:** *Learning is enhanced when material extraneous to the learning process is excluded.*

- **Signaling principle:** *Learning is enhanced when essential material is highlighted as it is being discussed.*

- **Redundancy principle:** *Learning is enhanced when narration is not duplicated as on-screen text when competing with dynamic visuals.*

- **Spatial contiguity principle:** *Learning is enhanced when corresponding words and images are presented in close proximity.*

- **Temporal contiguity principle:** *Learning is enhanced when corresponding words and images are presented simultaneously.*

For the management of essential progressing, three principles are given. These principles intend to address the instructional problem of essential overload, which can occur when a fast-paced multimedia lesson contains material thait is complicated for the learner, and the density of this material is too high. The principles of essential processing management are:

- **Segmenting:** *Learning is enhanced when a multimedia message is presented in learner-paced segments rather than a continuous unit.*

- **Pre-training:** *Learning is enhanced when main concepts of the multimedia message are presented in its beginning.*

- **Modality principle:** *Learning is enhanced when words are presented as narration rather than as on-screen text.*

Finally, the principles of generative processing fostering are given. These principles are intended to use social cues to prime the leaner's motivation to exert effort to make sense of the material. According to Mayer, "social cues in a multimedia message such as the style of conversation, voice and gestures may prime a sense of social presence in learners that leads to deeper cognitive processing during learning and hence better test performance". The last four principles are:

- **Personalization principle:** *Learning is enhanced when words are put in a conversational style rather than a formal style.*

- **Voice principle:** *Learning is enhanced when words in a multimedia message are spoken in a human voice rather than in a machine voice.*

- **Embodiment principle:** *Learning is enhanced when onscreen agents display human-like gesturing, movement, eye contact and facial expression.*

- **Image principle:** *Learning is not enhanced when the speaker's image is on the screen rather than not on the screen.*

The 12 principles described in this section will function as the basis on which the videos created for this thesis shall be designed. Following these principles should, according to Mayer, as well as collegial and personal experience, produce videos that are both usable and useful for students in the Remedial Instruction.

2.7.3 Bloom's Taxonomy

Originally created in 1956 under the leadership of educational psychologist Dr. Benjamin Bloom, the Bloom taxonomy of learning domains was a tool for professionals in education to promote higher forms of thinking in education, such as analyzing and evaluating concepts, processes, procedures and principles. It is often used when designing educational, training and learning processes [4]. In the mid-nineties, the Bloom taxonomy was revised by a former student of Bloom, Lorin Anderson. Anderson and her colleagues reorganized the original domain into a new one accoding to Table 2.2.

The Bloom taxonomy builds on itself from the bottom up. When considering remedial mathematics, the first three parts are the most important: remembering, understanding and applying. A student should start with *remembering*, the process of recalling or retrieving previous learned information. This is followed by *understanding*, which means comprehending the meaning, translation, interpolation and

Table 2.2: The difference between Bloom's original and revised taxonomy [1]. Note that in the revision process the "Synthesis" was replaced by "Creating", and "Evaluation" by "Evaluating", and the order of these two was flipped.

Original Domain	**New Domain**
Evaluation	Creating
Synthesis	Evaluating
Analysis	Analyzing
Application	Applying
Comperehension	Understanding
Knowledge	Remembering

interpretation of instructions and problems. It also includes stating a given problem in one's own words. Note that this is a critical part in mathematics as discussed earlier in this thesis: often students who face problems in mathematics find the language of mathematics difficult. Last of the important domains for remedial mathematics is *applying*, in which students use a concept in a new situation, or unpromptedly use an abstraction. A student might also apply something they learned from the material into novel situations in their own work.

Understanding the way students learn is key to successful educational multimedia creation. Using the points described above and concentrating on the skill level of students, the experiment in the Remedial Instruction can be seen as having the best possible effect. Bloom's revised taxonomy provides a great tool for this, as the concept of remember-understand-apply is quite straightforward.

2.7.4 Gagné's Nine Events of Instruction

Robert Mills Gagné was an educational psychologist, who is most famous for his work on developing a framework for what he and others believed to be "good instruction". The summarization of his works is often called *the Gagné assumption*. The core of this assumption is that different types of learning exist, and these different types of learning need to be addressed in order to attain most of instructional goals.

The most interesting of Gagné's works for this thesis are the *Gagné's Nine Events of Instruction*. Gagné proposed a series of events which follow a systematic instructional process. It should be noted that Gagné's theory takes from the slightly dated behavioristic view on learning. The nine events will be detailed below, and regardless of their age, if used in conjunction with Bloom's revised taxonomy, they should enable a teacher to design engaging and meaningful instruction.

The following nice steps have been adopted from Gagné, Briggs and Wager (1992) [10].

1. **Gain attention of the students:** Ensure the learners are ready to learn and

participate in activities by presenting a stimulus to gain their attention.

2. **Inform students of the objectives:** Inform students of the objectives or outcomes to help them understand what they are to learn during the course. Provide objectives before instruction begins.

3. **Stimulate recall to prior learning:** Help students make sense of new information by relating it to something they already know or something they have already experienced.

4. **Present the content:** Use strategies to present and cue lesson content to provide more effective, efficient instruction. Organize and chunk content in a meaningful way. Provide explanations after demonstrations.

5. **Provide learning guidance:** Advise students of strategies to aid them in learning content and of resources available.

6. **Elicit performance (practice):** Activate student processing to help them internalize new skills and knowledge to confirm correct understanding of these concepts.

7. **Provide feedback:** Provide immediate feedback of students' performance to assess and facilitate learning.

8. **Assess performance:** In order to evaluate the effectiveness of the instructional events, you must test to see if the expected learning outcomes have been achieved. Performance should be based on previously stated objectives.

9. **Enhance retention and transfer to the job:** To help learners develop expertise, they must internalize new knowledge.

Analyzing this list provides interesting ideas about the tools the thesis is built on. The steps and their cooperation with Mayer's principles and Bloom's Revised Taxonomy will be examined in chapter three.

2.7.5 Echo360 Video Service

The Echo360 video service has been designed to transform teaching and learning through active learning technology. It is a learning environment originally designed for lecture capture, with many active learning tools implemented inside it, such as the ability to take notes, asking questions about specific parts of the lecture, discussing the lecture, organizing polls and quizzes etc. The system works on multiple platforms as well, as it includes support for phones, tablets and laptops. Even if the system was originally designed for lecture capture, in this thesis it will be used for the mathematics videos in the Remedial Instruction.

The analytics tools of Echo360 will be used to study the usefulness of the supportive video material. Echo360 functions in the Moodle2 enviroment currently in use at TUT, and the university has bought the Echo360 system in order to develop its pedagogical solutions. Echo360 is a commercial software, and it should be noted that the results in this thesis, while difficult to attain without the software, should be considered by anyone trying to duplicate this study. [7]

3. RESEARCH METHODOLOGY AND MATERIALS

In the previous chapter, the theoretical background and problem-setting of the Remedial Instruction were discussed in order to give the reader a more in-depth understanding of the problem this thesis addresses, and to direct the methods of research in the thesis. In this chapter, these guidelines are used to explain, justify and validate the methods and tools used in the study of educational videos.

3.1 Research Questions

There are four research questions in this thesis. The first is more of a stand-alone topic on the side of qualitative research, while the last two are very much interlinked and focus on the quantitative study of the effectiveness of mathematics videos and the use of tools in the Remedial Instruction. The research questions are

1. What makes a good mathematics educational video, and what is necessary for a teacher to be able to create such multimedia?

2. What kinds of tools are used by students to complete the Remedial Instruction? Can it be empirically shown, that mathematics videos are effective in supporting students in their completion of the Remedial Instruction, and if so, is it possible to identify the type of student that would gain most from this type of multimedia?

3. Can the results found in Question 2 be verified by using a questionaire answered by the students taking part in the Remedial Instruction, and if not, what are the differences between the empirical observation and the subjective answers of the questionaire?

4. How should educational videos and other tools be developed and used in the Remedial Instruction to improve their effectiveness in the future?

These questions, as previously noted, will be answered in two ways. The first question will be answered by looking into previous, successful attempts at creating educational videos. By using the information of former studies and projects, and combining them with theory and the researcher's own practical experiences, the thesis attempts to create a simple, elaborate and easy to follow framework for creating quality multimedia for teaching. For questions two, three and four, the statistical methods used on the data will be discussed, and later, the results of these observations will be presented in the next chapter. The models and tools presented in the previous chapter such as the ADDIE model, TUT mathematics learner profiles, Mayer's principle of multimedia design and Echo360 video platform will be used.

3.2 Creating Videos for Educational Purposes

In this section the ways of creating succesful educational videos are discussed. Important viewpoints on the topic include the thesis's first research question: what makes a good educational video, and what are the requirements in order to be able to create one? Also, the pedagogical strategies and successful examples presented in Chapter 2 are summarized and applied.

3.2.1 Chosen Methods and Alternatives

There are many ways to present mathematics on a video: pen and paper work, slideshows, drawing tables etc. After many attempts to create a working setup for recording pen and paper work, it was decided that the tools required for high quality work done this way would be too expensive. Thus, in this thesis the videos were created using the Latex Beamer toolkit and the Camtasia Studio video capture software. Voice-over was done by the author. This method was chosen for the following reasons: easiness of setting up, affordability (free of costs) and the author's own familiarity with tex-based documents. The aim of the thesis is to work as a starting point for teachers interested in making educational videos, and for this, the first two of these steps are really important. Also, referring to the principles of multimedia design by Mayer presented in the previous chapter, the principles of *personalization* and *voice* will be met.

The videos that were created were split in small digestable parts. The parts were of maximum 10 minutes in length, and this addressed the *segmenting principle*. Due to the *pre-training principle*, the main concepts were presented at the beginning (and also in the topic) of the videos.

Other alternatives for creating the videos include: using tablets for drawing, power point slideshows, using a white- or blackboard or pen and paper, having the instructor on-screen etc. These options were opted out of due to the Mayer principles, personal experience in filming, and the attempt at maintaining a low barrier for entry for new teachers trying to create their own videos. To summarize: less is more, and simple is beautiful. The Beamer toolkit achieved these goals really well.

Applying Pedagogical Strategies

For the sake of usefulness, the pedagogical frameworks presented in Chapter 2 were applied in the production of educational multimedia. By utilizing the remember-understand-apply approach of Bloom, together with the nine steps of Gagne, and remembering the principles of Mayer, the videos are created from a pedagogically firm standpoint. Thus it is necessary to discuss the three views in combination.

The first step of Gagne's is the attention gain. Gaining the attention of the students is already achieved when they click to start the video. However, maintaining that interest is the difficult part. This would be answered in part by the Mayer principle of *segmenting*. If the video is short enough, and especially captivating at the beginning, it is more likely to attain the student's interest throughout the video. The second part, informing students of the objectives, is a natural step to take here. It is also in line with the Mayer principle of *pre-training*. For Bloom's taxonomy in remedial instructions, all these are a part of the remember-phase.

The third Gagne step, stimulating recall to prior learning, can be done verbally on the tape. Stating where to find relevant information (high school mathematics books, Math-Bridge learning material, or former videos in the series) encourages students about the easiness of finding supportive material. This is a transition from the remember- to the understand-phase of Bloom. The fourth Gagne step, presenting the content, tells the instructor to organize and chunk content in a meaningful way. This is in line with the *segmenting* principle of Mayer. It should be noted that the explanations should follow demonstrations, not precede them.

The fifth Gagne step, providing learning guidance, is closely interlinked with the third step. In remedial mathematics, learning guidance should be almost completely related to past experiences in the topics. Resources are abundantly available for students. Steps 6, 7 and 8 are all done by Math-Bridge. The system provides exercises for the student, gives immediate feedback on problems, and thus assesses performance. The Remedial Instruction is in itself an embodiment of the ninth step, enhancing retention and transferring to the job. This is clearly the apply-step of Bloom's taxonomy.

According to the above, the seed of quality instruction is present in the Remedial Instruction. To help students get underway in their training, instructional videos can provide invaluable support, and the earlier steps of quality instruction can be enforced using carefully designed educational videos. To sum up, the videos should:

1. gain viewer attention by introducing the topic both verbally and visually,

2. maintain viewer attention by promising a digestable video length,

3. clearly state the educational goal of the video in a conversational manner,
4. stimulate recall to prior learning by presenting something familiar to the viewer,
5. present the content in a clear, pedagogically comprehensive style,
6. close out the video by providing instructions on how the viewer can train the skills themselves.

By using these six steps, the videos are guaranteed to be of educational value. The steps are further modified and enhanced in the next chapter when creating the Framework for Educational Videos.

3.2.2 Necessary Equipment

The production of educational videos would be impossible without a studio. Necessary equipment for a studio include at least the following: a camera, a computer with screen capture and editing software, and the tool used to present the topic at hand. If working with pen and paper or similar tools, it is crucial to have a good light source (at least 5500 K of color temperature), and the camera that records the actions taken by the hand should be able to film in high definition (HD). In this thesis however, the only necessary tools were the free Latex and Beamer software toolkits, and a computer with Camtasia Studio video capture software, and a microphone.

When creating the voice-over for videos, the speaker should be in a quiet place, preferably an office room with no loud fans or anything similar. The speaker should use a calm, discussion like voice and articulate everything clearly. A conversational tone should be maintained in order to adhere to the Mayer principle of *voice*.

3.3 Echo360 Analytics

The Echo360 service provides teachers with the possibility of following their students actions in the course through the videos published in the system. As Echo360 is at its best at providing a platform for lecture videos, this thesis will focus on the use of Echo360 as a platform for short educational videos. The theoretical possibilities are given in this section, and in the next chapter some consideration will be given to see how the system actually performed as a platform for these kinds of short videos.

Engagement is an important concept with Echo360. A teacher can define what is important and critical for students during the course. There are a total of six factors which are *attendance*, *video views*, *presentation views*, *Q&A*, *notes* and *activities*.

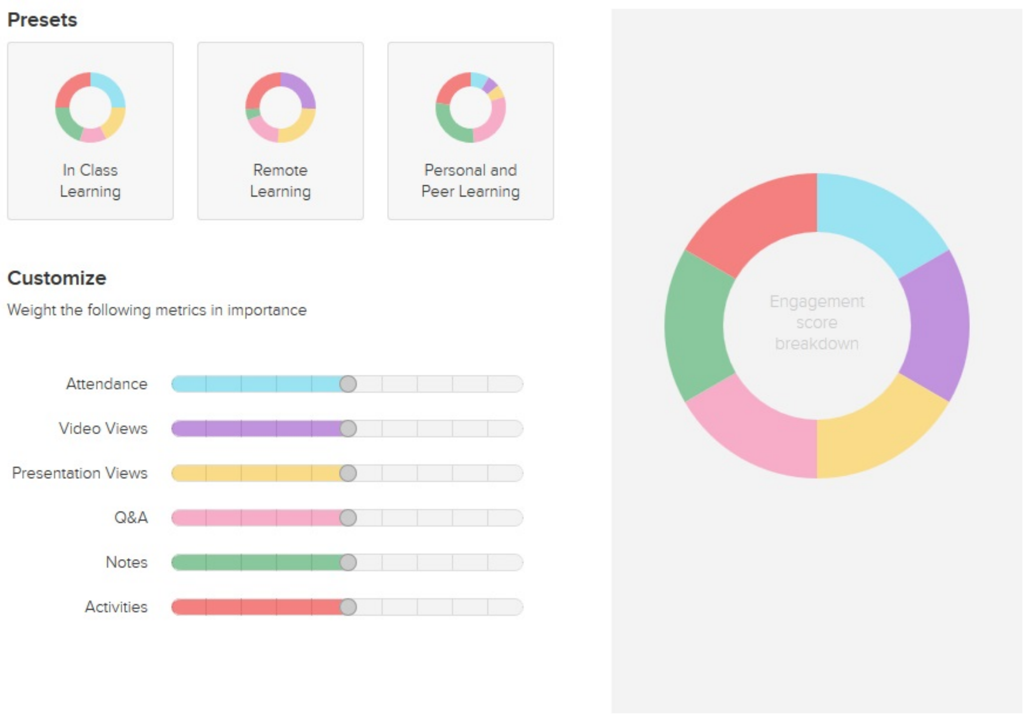

Figure 3.1: Screenshot of the Echo360 engagement settings tool. The sliders can be used to control the importance of the six given aspects of course engagement. The pie chart on the right shows a graphical representation of the engagement weights. The shown pie charts are the default settings.

All of these can be given their own weight for in class, remote and personal and peer learning. Together, all of these define the student's engagement in the course.

For short videos, in class learning is the most important of these three learning activities. It is most interesting to find out how students act when watching the videos. Thus the most important aspects are *attendance* and *video views*. The other weights can be minimized. Students who watch 5% of any video will have a registered view.

Echo360 also offers an intuitive dashboard that delivers single-screen insights into student, class, course and content performance. The dashboard offers the teacher the ability to track recording views, questions asked, responses to in-class quizzes and more. A sample picture of the dashboard is given below.

One more viewpoint that the Echo360 service provides for the teacher is student specific activity. For each video (or classroom, as the system calls them), the teacher can see if a given student has watched the video, how many times they've viewed the attached presentation, how many questions they have left for the teacher, how is their participation in quizzes and how many correct answers have they gotten, and finally, how much is the word count in their notes.

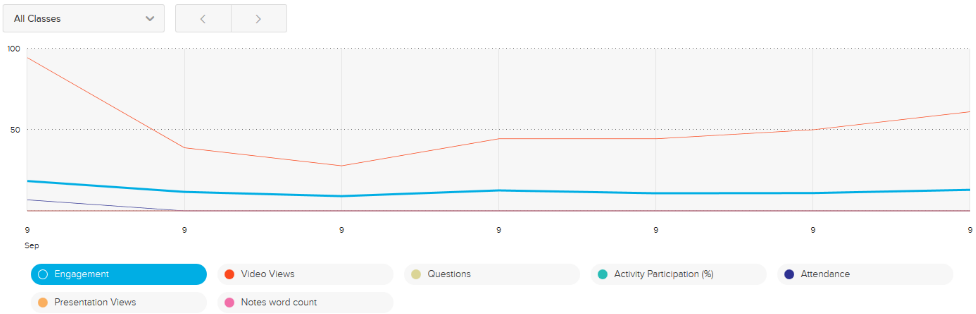

Figure 3.2: Screenshot of the Echo360 engagement dashboard. The seven items in the bottom are clickable and change the y-axis to correspond to the relevant aspect (engagement is measured in percentages). The figure shows data from the Remedial Instruction.

3.4 Questionaire

In order to verify the empirically observed data of the Remedial Instruction result analysis as well as the data gained from Echo360 analytics, a questionaire (see Appendix A) was prepared to ask those students participating in the Remedial Instruction what they thought about the videos. The students were also asked questions about their work in the instruction. The questionaire was prepared according to the concept of triangulation - the way of approaching a phenomena from different points of view [17]. When speaking of the Remedial Instruction and the videos created for it, it was decided that the questionaire would include the following points of view:

- If the student watched the videos, they were asked about

  The *added benefit* gained from the videos

  The *clarity* of the videos

  The *quality* of the videos

  The *availability* of the videos

  The *duration* of the videos

- If the student had not watched the videos, they were asked for reasons in

  The *availability* of the videos

  Their *previous knowledge* of the video's subject

  Their *bias* towards educational videos

  Their *use of other tools*

- The students were asked about their work in the Remedial Instruction regarding

  Their *use of time*

Their *tools used*

The instruction's *difficulty level*

The *added benefit* gained from the instruction

Their use of *teamwork*

Their *user experience when needing support*

The points of view in the case of the videos being watched were prepared using Mayer's principle of quality multimedia and the aim of the department, which is of course the added benefit gained from the videos. In the case that the student hadn't watched the videos, the aim was to understand the reason why. In addition to these points of view, the questionaire delves into the student's work during the Remedial Instruction, including the tools that they used and the time it took for the students to finish.

The questionaire questions and their research goals

In this section the questions used in the questionaire will be briefly presented and their reasoning explained. The questions use either yes/no or the Likert scale as their scaling method.

1. Student number
2. Did you watch the Remedial Instruction videos? (yes/no)

The first two questions are quite straightforward. The student number will be used as a key to connect the questionaire answer with the corresponding the student's results in the Remedial Instruction. Answering *yes* to the second question will give the student questions 3 to 7, while *no* gives questions 8 to 12.

3. I felt that watching the videos helped me in solving the Remedial Instruction exercises. (Likert)
4. The subject matter was presented clearly in the videos. (Likert)
5. The sound and picture quality of the videos was good. (Likert)
6. The videos were easily available. (Likert)
7. The videos were suitably long in duration. (Likert)

Question 3 addresses the added benefit that the videos provided for the students. Questions 4-7 try to measure how well the videos address the Mayer principles of *coherence*, *spatial contiquity*, *temporal contiquity*, *segmenting* and *voice*.

8. I didn't watch the videos, because I did not know there were videos available. (Likert)

9. I didn't watch the videos, because I already knew how to solve the problems they addressed. (Likert)

10. I didn't watch the videos, because I dislike educational videos. (Likert)

11. I didn't watch the videos, because I used other tools to finish the problems. (Likert)

12. I didn't watch the videos, because of another reason (specify below). (open)

If the student answered "no" to question 2, then they were presented with questions 8-12. These questions aim to find out the main reasons in the case that the student had not watched any videos. The reasons presented here are some of the main reasons why educational multimedia could be left unused. If question 8 gains a lot of popularity, then we could easily see that making the videos more easily available would probably result into more people watching them.

13. The Remedial Instruction lasted for four weeks. I solved most of the problems (In the first/second/third/fourth week / I solved problems throughout the four weeks)

14. The amount of hours I used on the instruction was approximately (0-5/5-10/10-15/15-20/20-25/25+)

15. Choose from the following all the tools you used in the Remedial Instruction:

    Pen & paper; Wolfram Alpha; CAS calculator; Function calculator; High school books; Remedial Instruction teaching material; Remedial Instruction model answers; Remedial Instruction educational videos.

Questions 13-15 aim to measure the student's work in the instruction. An optimal (or rather, most hoped for) case would be that the student solved problems throughout the four weeks, used approximately 10-15 hours on the instruction, and didn't use a lot of Wolfram Alpha or CAS calculator when working, but rather focused on pen & paper solutions with the help of their old and new study material. This is due to the fact that Engineering Mathematics courses at TUT do not allow calculators to be used in the final exam.

The last section focuses on the student's feelings about the Remedial Instruction:

16. The problems in the Remedial Instruction were of reasonable difficulty. (Likert)

17. I felt that the Remedial Instruction helped me to remember high school mathematics. (Likert)

18. I felt that the Remedial Instruction helped me in the first course of Engineering Mathematics.

19. I worked together with my fellow students to solve the problems.

20. If I needed help with the Remedial Instruction, it was easily available.

The questionaire ends with questions about problem difficulty, added benefit, teamwork and user experience. The question about teamwork is increasingly interesting, as former acts of supportive mathematics at TUT have aimed to enable students to work with each other and thus get peer support and to better network amongst themselves. Earlier experience has taught that students can gain a lot from working together in groups.

3.5 Tools for data description and analysis

In this thesis, most of the mathematical tools used are from the field of statistics. Statistics can be seen as two separate fields when it comes to research: descriptive and inferential statistics. In this thesis, most of the weight is given to descriptive statistics, as the collected data must be analyzed using pedagogy, but the descriptions provided by statistics are invaluable. The statistics tools used in this thesis are mainly from two sources: Walpole et al. [27] and Metsämuuronen [17].

Describing data

In statistics, the basic parts that are measured are called *statistical units*, which could be for example students. These statistical units combined form a *sample*, and the whole group of statistical units is called a *population*. Data is collected from the statistical units in form of *variables*, which could be a point score in a test, or an exam grade. By collecting the variable observations for the whole sample we attain the observational data $x_1, x_2, \ldots, x_n$, where x_i is the *observational value* for a single variable for a single statistical unit. In a case with multiple statistical units, the group of x_i will form a vector. For the scope of this thesis, this vector is only considered as an arranged set of numbers, so further analysis is not necessary. When multiple observations are brought together in a table, they form a *data matrix*. This has been done in Table 3.1.

Table 3.1: An example data of 12 students.

Student number	BST Score	Exercise points	Exam grade
6841	10	45	5
8641	3	20	1
8146	8	33	4
1387	4	53	2
2436	5	68	4
2575	3	46	3
2543	15	70	5
9292	3	9	0
8407	12	22	3
8245	9	44	3
4747	7	30	3
6421	6	29	2

Frequency

A reasonable start for describing any data is to calculate the amount of different observed values. The amount attained is called *frequency*. Frequency can be expressed either as a concrete number or as relative percentage value. For example, if the exam grades in Table 3.1 are studied, the following frequencies f and percentage values $f\%$ can be attained:

Table 3.2: Grade distribution

Grade	f	$f\%$
0	1	8,33 %
1	1	8,33 %
2	2	16,67 %
3	4	33,33 %
4	2	16,67 %
5	2	16,67 %
Σ	12	100 %

In the case of a larger sample size, a better way to present data rather than a table would be a *histogram*. A histogram is a bar plot that gives each variable observation their own bar, and the length of the bar is the frequency of the observation. For any histogram, the limit values for the factors have to be determined. In this thesis, the Likert scale was commonly used. The Likert scale used in this thesis has five values: "Strongly disagree", "Somewhat disagree", "I don't know", "Somewhat agree" and "Strongly agree". In the example above in Table 3.2, these frequencies can be shown in a histogram as in the figure below.

The information gained from Figure 3.3 immediately lets the reader know which are the greatest frequencies, and in the case of using the Likert scale, one can

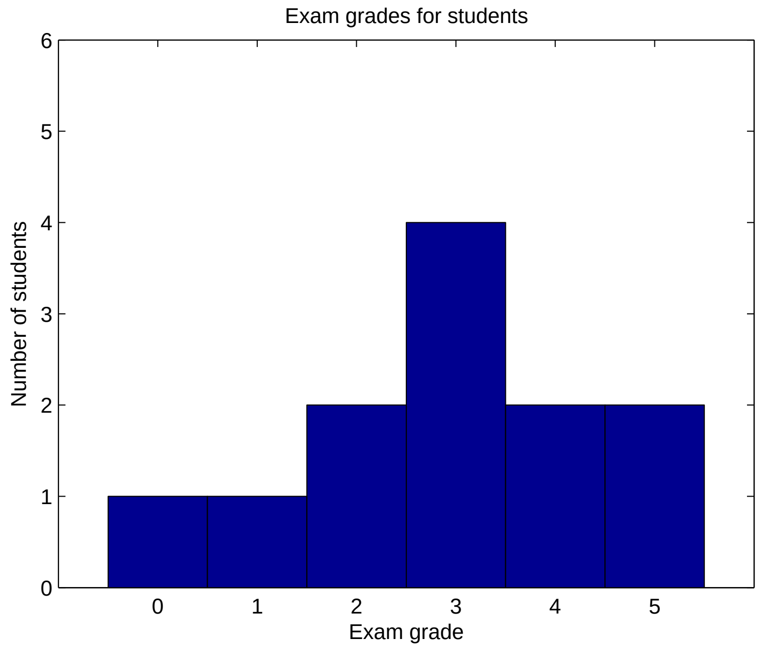

Figure 3.3: Example of a histogram for the student exam grade data in Table 3.1.

immediately state the result of the answers. Also, in the data that has been studied more extensively, histograms provide a preliminary result of the mean and deviation, which will be discussed next.

Mean, standard deviation and standard error

The most common descriptive tools used on any data are different center and deviation numbers. These provide a rough idea about the measured data, and in some cases, they depict the most important aspects of the overall data very well. In the scope of this thesis, the most important descriptive tool is the *sample mean*, which is simply a numerical average defined as [27]:

Definition 3.5.1. Suppose that the observations in a sample are $x_1, x_2, ..., x_n$. The *sample mean*, denoted by $\bar{x}$ is

$$\bar{x} = \sum_{i=1}^{n} \frac{x_i}{n} = \frac{x_1 + x_2 + ... + x_n}{n}. \tag{3.1}$$

△

The mean is attained by adding all the observations together and then dividing the sum by the number of observations. However, it is not very usable on the Likert scale, unless the different options are given numerical values from 1 to 5. Still, if the average in this method ends up at 3 (I don't know), with most answers either agreeing or disagreeing, then using mean is pointless.

Another important descriptive is *standard deviation*. In order to define standard deviation, first *variance* must be defined. Variance is the most commonly used form of deviation in statistics, and is defined as follows [27].

Definition 3.5.2. The *sample variance*, denoted by s^2, is given by

$$s^2 = \sum_{i=1}^{n} \frac{(x_i - \bar{x})^2}{n-1}. \tag{3.2}$$

The sample *standard deviation*, denoted by s, is the positive square root of s^2, that is,

$$s = \sqrt{s^2}. \tag{3.3}$$

△

The difference between two samples can't be determined by only looking at the mean. For this reason, the addition of standard deviation is fruitful. Consider two samples, one that has a peak in the middle, and one that has two peaks on both sides of and at equal distance from the middle. These two data sets would have similar means but vastly different variances. Also, if the standard deviation is known, then the variance can be attained by raising to the power of two. Variance can be used in calculating of multiple statistical characteristics.

Finally, the standard error of the mean (also referred to as standard error in this thesis) is defined [27].

Definition 3.5.3. Let s be the sample standard deviation, and n the size of the sample. The standard error of the mean is defined as

$$SE_{\bar{x}} = \frac{s}{\sqrt{n}}. \tag{3.4}$$

△

Pearson's Product-Moment Correlation Coefficient

The Pearson's product-moment correlation coefficient, often simply called *correlation*, denoted r, is a measure of the strength of a linear association between two variables x and y, giving a value between +1 and -1 inclusive. For r, value of 1 means total correlation, 0 means no correlation and -1 means total negative correlation. It is often used to measure linear dependence between two variables.

Definition 3.5.4. The *Pearson product-moment correlation coefficient* for variables x and y, denoted by r_{xy}, is given by [17]

$$r_{xy} = \frac{n\left(\sum_{i=1}^{n} x_i y_i\right) - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i}{\sqrt{\left[n\left(\sum_{i=1}^{n} x_i^2\right) - \left(\sum_{i=1}^{n} x_i\right)^2\right]\left[n\left(\sum_{i=1}^{n} y_i^2\right) - \left(\sum_{i=1}^{n} y_i\right)^2\right]}}. \tag{3.5}$$

△

As an example, the correlation coefficient for the BST score and exam grade in Table 3.1 is calculated.

Table 3.3: Correlation data of BST score and exam grade for the example student data. x is BST score, y is exam grade.

i	x	y	xy	x^2	y^2
1	10	5	50	100	25
2	3	1	3	9	1
3	8	4	32	64	16
4	4	2	8	16	4
5	5	4	20	25	16
6	3	3	9	9	9
7	15	5	75	225	25
8	3	0	0	9	0
9	12	3	36	144	9
10	9	3	27	81	9
11	7	3	21	49	9
12	6	2	12	36	4
$\sum_{i=1}^{n}$	85	35	293	767	127

By applying (3.5) to the data in Table 3.3, the correlation coefficient is

$$r_{xy} = \frac{12 \cdot 293 - 85 \cdot 35}{\sqrt{[12 \cdot 767 - 85^2][12 \cdot 127 - 35^2]}} = 0{,}703,$$

which would indicate that correlation is positive. The size and "goodness" of the correlation is relative to the case. In human sciences, correlations over 0,80 are rarely encountered, but in natural sciences, possibly using high-tech instruments, the desired correlation could be over 0,80.

Regarding the interpretation of correlation, several tools are given. Most of these tools are somewhat arbitrary and should not be observed too strictly. However, [17] provides a couple of useful examples: *correlation squared* r_{xy}^2 and *correlation significance*. Correlation squared implies how much of a variable's variance is explainable by another variable. For example, for a correlation of 0,90, r_{xy}^2 would be 0,81. This would mean a significant connection between the factors, since they could "explain

81 % of each other". For the example data above, $r_{xy}^2 = 0{,}495$. This would mean that correlation could exist.

Another form of evaluation of correlation is using a test value t which for null hypothesis "correlation coefficient does not differ from zero" follows t-distribution with $n-2$ degrees of freedom:

$$t = \frac{r_{xy}\sqrt{n-2}}{\sqrt{1-r_{xy}^2}}. \tag{3.6}$$

Looking at the previous example data, t is

$$t = \frac{0{,}703 \cdot \sqrt{12-2}}{\sqrt{1-0{,}703^2}} = 3{,}126.$$

The test value gives a result of 3,126. The 5 % risk level critical point in the t-distribution table [17] for 10 degrees of freedom is 2,228. In order for the correlation coefficient's difference from zero to be statistically significant, it should have gotten a value over 2,228. This happened, and thus in the example, the correlation coefficient meaningfully differs from zero, meaning that there is statistical evidence of a linear connection between the two variables.

Finally, correlation is easily studied by the human eye when the given data is plotted in a graph, and a least squares line is fitted to the plot. This was done in Matlab, and the code is presented below. The graphic given by this code is shown in Figure 3.4.

```
% Least square regression example

X = [10 3 8 4 5 3 15 3 12 9 7 6];
Y = [5 1 4 2 4 3 5 0 3 3 3 2];

fig = figure();
plot(X, Y, 'rs', 'Linewidth', 2)
xlim([0 16])
ylim([-0.2 5.2])
xlabel('BST points')
ylabel('Exam grade')
title('Exam grades in relation to BST points')

%%%% Y = HA

Y = Y';
X = X';
```

```
H = [ones(length(Y),1), X];
Astar = inv(H'*H)*H'*Y;
Ytilde = H*Astar;
hold on
plot(X,Ytilde, 'k-', 'Linewidth', 2)
```

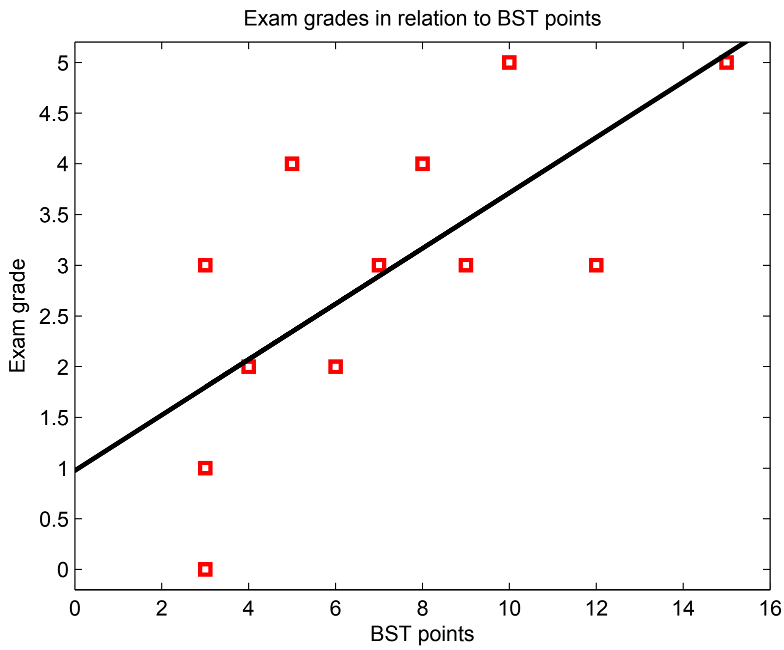

Figure 3.4: Example of a least squares line fit to a data. The data in red squares is from Table 3.1, and the black line was fitted using the code above.

In a graph like this, each data point has a certain vertical distance from the fitted line. The greater this distance is, the closer the correlation of the factors is to zero. In a case of total correlation, i.e. $r_{xy} = 1$, the data points would rest on the fitted line. As the correlation was already found to exist, it is not a bit surprising that the points are quite far from the fitted line. This can of course be adjusted by manipulating the scale of the y-axis.

4. RESULTS AND DISCUSSION

In this chapter, the results of this thesis are presented. Also, some discussion on the different results, as well as some answers to the thesis's research questions, are given. Later in the final chapter, the results of this chapter are brought together to complete the study on educational videos in the Remedial Instruction.

4.1 Framework for Educational Videos

This section aims to provide answers to the first research question: "What makes a good mathematics educational video, and what is necessary for a teacher to be able to create such multimedia?" In order to answer this question, a framework for educational videos (FEV) was created. The FEV follows the six guidelines provided in Chapter 3 and is built around five core concepts: *attention*, *goal*, *prior learning*, *content* and *future*. FEV can also be seen as the "design" part of the ADDIE model when discussing creation of educational videos.

The underlying reason for creating the FEV is very simple. When creating materials for teaching at a school or university, common sense will take an educated teacher a long way. However, at times everyone makes mistakes and their judgement about their own material can falter. If the material was something very simple, say a lecture, it will not take a lot of time to start over and create a totally new lecture with a different point of view. However, with educational videos, the amount of time needed to create a quality product is much longer. In order to change a complete product, one would have to redo both filming and editing, both of which take up a considerable amount of time. Thus it became clear that some support is needed for video design, and this is why the FEV was created.

The biggest problem that educational videos face is their own style of teaching: videos make the student a very passive participant, which can be a somewhat difficult role for the modern student. Some students today are accustomed to be constantly fed with stimulants from different sources: social media, television, their mobile phones and so on. It is very easy for the passive viewer to change from this uncomfortable role into a more active one by abandoning the video and doing something different instead. This concept of *attention* needs to be addressed first in order to create successful multimedia.

A graphic demonstration of the FEV is shown in Figure 4.1.

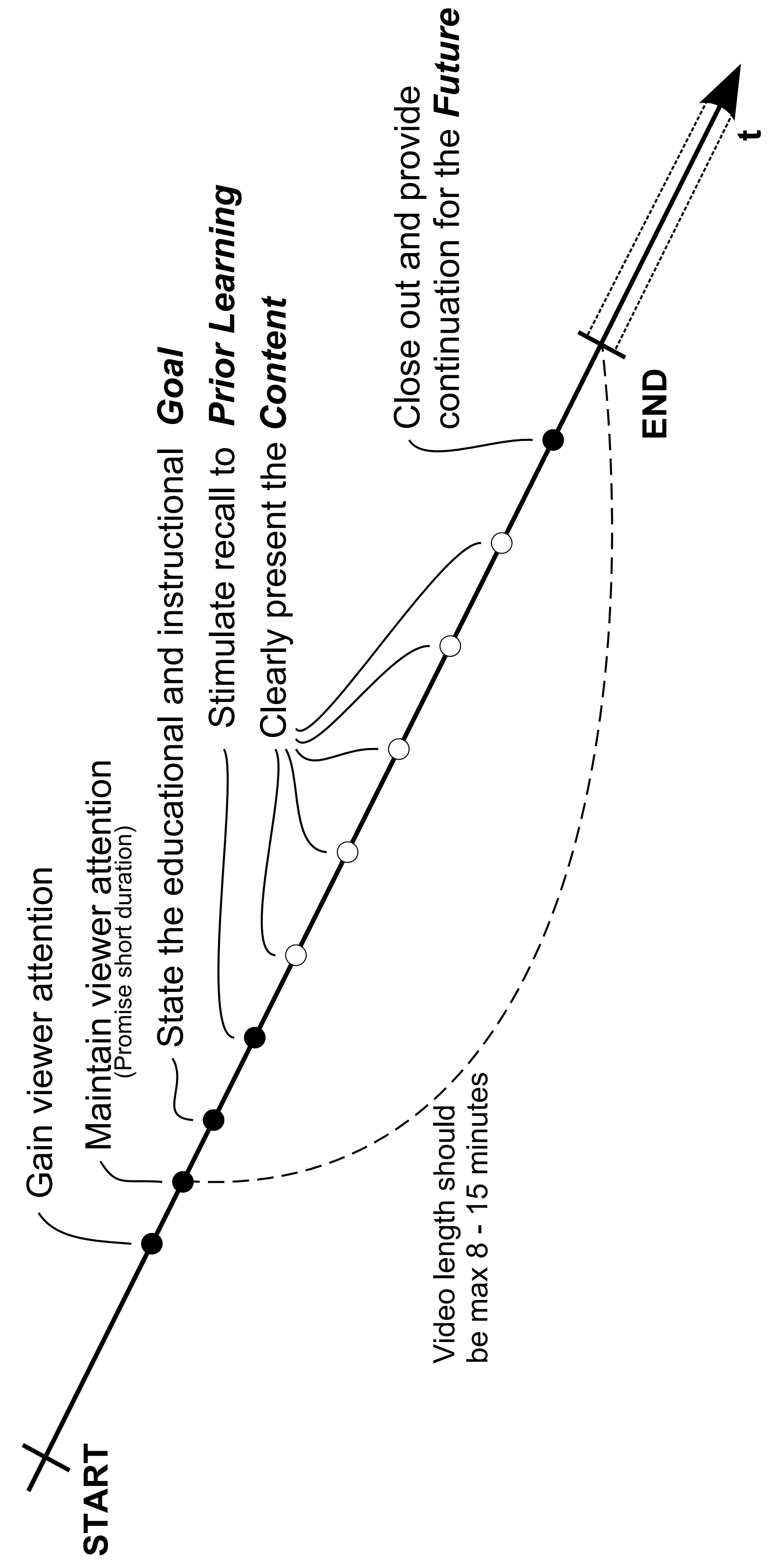

Figure 4.1: A graphic demonstrating the Framework for Educational Videos

How then should a teacher attempt to gain the viewer's attention? The easiest way to do this is in line with Mayer's idea of reducing extraneous processing: extraneous processing is caused by poor instructional design, and thus, by showing good video and sound quality, as well as using a clear human voice and/or clear visual tools, the student is assured that the video is worth their time. This pulls the student in and makes it easier to proceed to the next step, *maintaining viewer attention*.

As discussed before, video length is very important. The Mayer principle of *segmenting* states that educational multimedia should be cut into "viewer sized" parts. This is crucial in maintaining viewer attention. If students are promised a 10 minute video instead of a two hours long lecture, they are much more likely to watch all of the material intensively. In the FEV, maintaining viewer attention is seen as a promise of reasonable video duration, and presentation of the video's content structure. Together, these both will help the student to ease into the process of managing their essential processing and thus working and learning.

After the *attention* of students has been gained, the next important step is to present the *goal* of the video. This could be the presentation of a given algorithm, the solution of a certain problem type or something similar. The first place where the students should see the video's goal is the title. In the video itself, the goal's statement should be given early and clearly, so that all essential processing can be directed towards this goal.

In order to achieve the video's *goal*, it would be best if the goal could be somehow tied together with *prior learning*. This means that just like in ordinary teaching of mathematics, the new topic should be derived from an old one. Consider for example the presentation of complex numbers. In high school mathematics, if the discriminant of a second degree polynomial is found to be negative, it is said that the polynomial has no real roots. However, the roots exist and they are complex numbers. On the other hand, all real numbers can be presented on a real axis. By adding another axis - the imaginary axis - to the space, we can give all complex numbers as vectors on this plane. This way, we tie the old knowledge in together with the new. Students will also have something that they can easily agree upon when the video is at its beginning.

After the *goal* is clear and students are rooted to the video by quality production and *prior learning*, it is time to present the *content*. The content should be separated into distinct parts, and not everything needs to be said at once. Remembering the Mayer principle of *segmenting* is once again valuable, as a single concept can easily be disected into multiple videos, and thus the material can be more easily studied at the student's own pace. As shown in Figure 4.1, multiple bits of content can also be given to the student in a single video. The teacher needs to find the balance of content versus segmenting. This can be done in many ways, one of which is trial and error, while others being for example looking at successful alternatives. Like in all other teaching, there is not one single correct way, but there can certainly be best found practices.

It is important to note some additional aspects of content presentation: if *prior learning* is not being taken into account, the students will find the *content* itself confusing, and this will lead into *attention* being directed elsewhere. Also, the content should be presented clearly (just as in all teaching), and the narrator should use a discussion style human voice when explaining the material. This is in accordance to the Mayer principles of *voice* and *personalization*.

After the content has been presented, the task of and educational video is almost complete. Extraneous processing has been eliminated, essential processing has been managed, and finally, generative processing should be fostered. Mayer explains generative processing as something that is "aimed at making sense of essential material, caused by learner's effort". This means that the teacher should make an effort to have students engage in activities that would cause them to use the material just learned. For example, students could be directed to some exercise problems that deal with the topic that was just discussed. Students could also be directed to a new video or another piece of multimedia that further explains certain topics, or is a continuation to the topic. Whatever the chosen method, it is important that the teacher provides the student *something to do with the content in the future*.

How then can a teacher with no previous expertise in educational multimedia accomplish all these tasks and provide quality material for their students? The first place to start is to think of an idea for a video. Often teachers have some topic that they would like to emphasize during their lectures but for lack of time can't. These topics are prime examples of content that could be explained by using videos. After the idea is ready, the teacher should start writing a *script*. When talking about the FEV, the ideas presented herein are best applied when the video is being scripted beforehand. Careful writing of different parts of the video will save a lot of worktime, as the structure and content of the video will be clear. Scripting is very important, and quality videos should be thought of as quality books: time and time again, a user can look it up and without outside assistance, understand the topic by reading/viewing the presented content, and working through the material that is aimed for generative processing. Scripting is also an important part of the ADDIE model (storyboard the design, plan & test using prototypes).

With the help of the FEV, a teacher can engage in an activity called the multimedia improvement cycle. Similar cycles are used in many other fields, and here it is also evident that creating and using videos in education is an ever-improving cycle of *thinking of an idea*, *scripting*, *filming and editing* and *using and testing*.

This cycle is given in Figure 4.2.

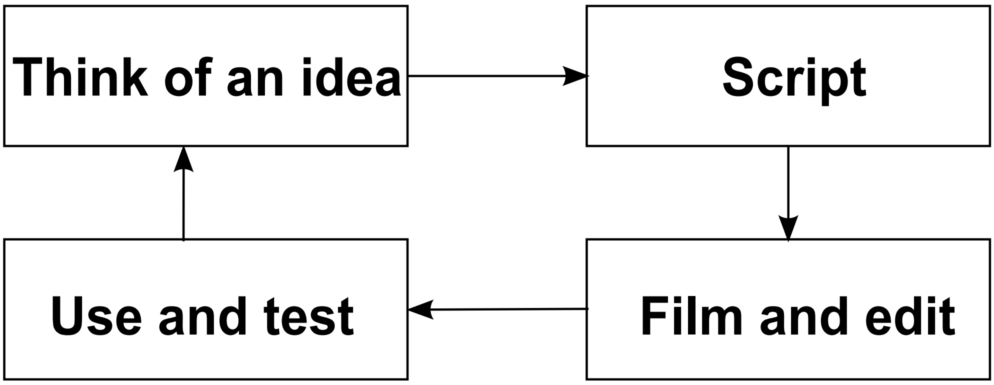

Figure 4.2: The multimedia improvement cycle. Note that this cycle is very similar to the ADDIE model cycle of analyse - design - develop - implement - evaluate.

It should be noted that in this thesis, the videos used to gain questionaire data and measure educational video effectiveness were done using this framework. Working in this framework should be easy for anyone, even if they do not have a lot of experience in videos.

4.2 Remedial Instruction videos

In this section, the Remedial Instruction videos are presented, and the FEV is shown in action. The screenshots presented below are from the videos used in the Remedial Instruction of fall 2015. The videos can also be found online at the department's channel: `https://www.youtube.com/channel/UC9gZ4VrQQIaYd-irZATtPRQ`.

Figure 4.3: Start of the video with the title. The title should clearly state the video's purpose. The above translates to "Integrating an absolute value expression".

Figure 4.3 represents the start of the video. In this part, the narrator instructs students about the topic of the video. Students might also at this point check the video's length. If it is too long (or too short), they could turn away from the video immediately. Quite quickly and without further delay, the video moves on to the next part, which is stating the educational and instructional goal.

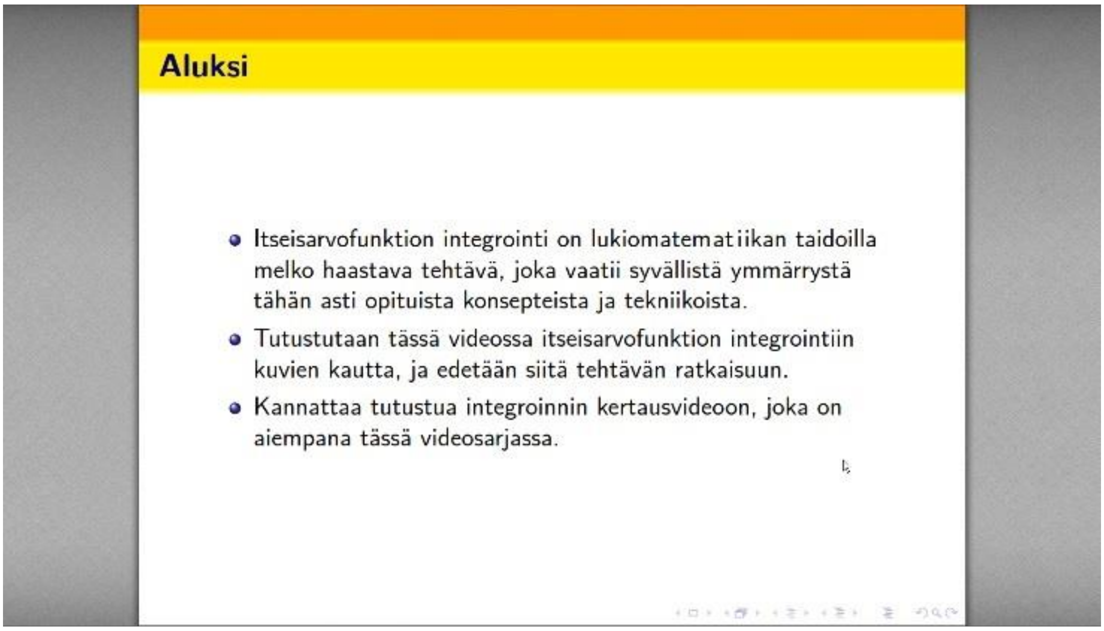

Figure 4.4: Stating the instructional goal and stimulating recall to prior learning. Also, if students could feel uncomfortable about the material that is assumed as prior knowledge, they can be directed to material that will help them. In this case, previous videos in this series are recommended.

After the goal of the video is clear, and students have been introduced to the topic by recalling their previous experience in the topic, it's time to start presenting content. In Figure 4.5, three screenshots are shown which demonstrate the addition of new material to the slide in parts. This is very easy to do using Beamer, since the `\pause` command will only reveal the material presented before the next `\pause` or the end of the slide.

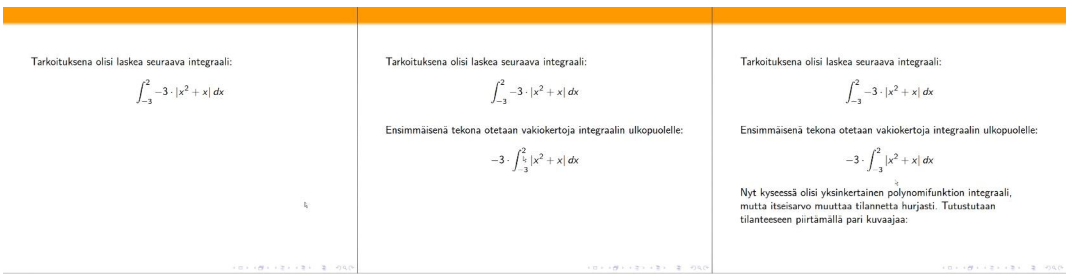

Figure 4.5: Multiple screenshots of a single slide. This is an example of presenting content in parts, mainly by adding a little bit of new material to the screen at a time. The text itself is about the integral of an absolute value function. Too much material on a slide can lead to extraneous processing, which will affect concentration.

Next, some of the capabilities of the Beamer package are presented. Beamer is a great tool for creating mathematical content, as the end result looks fantastic, and combined with the FEV, the material is clear and consistent.

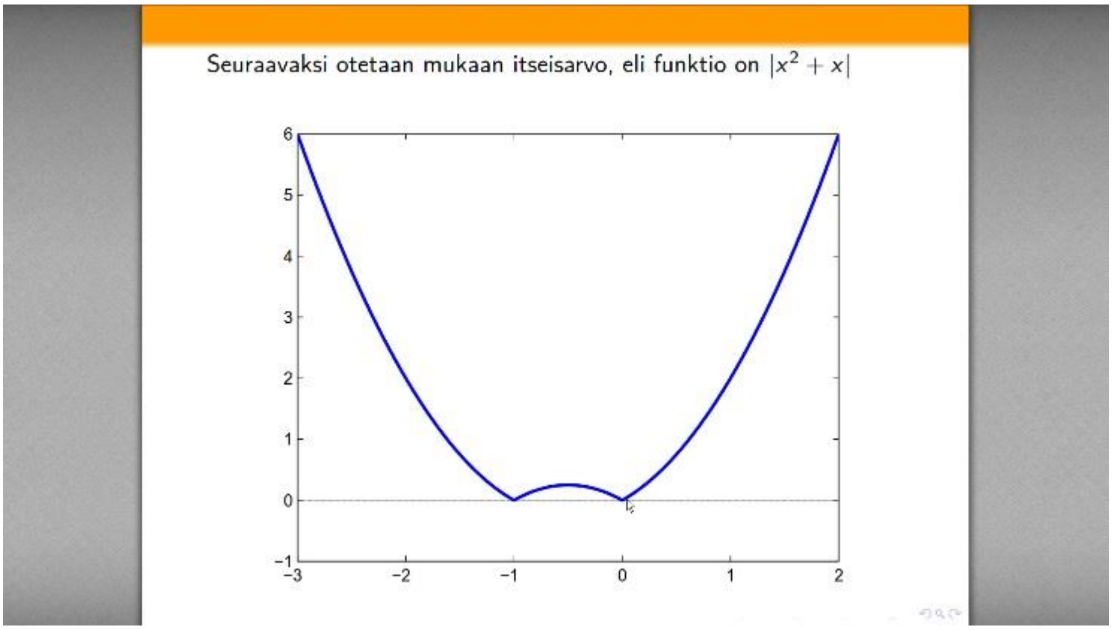

Figure 4.6: An example of the capabilities of the Beamer package in presenting graphics. The graph was drawn in Matlab, saved as an .eps -file and then added to the video.

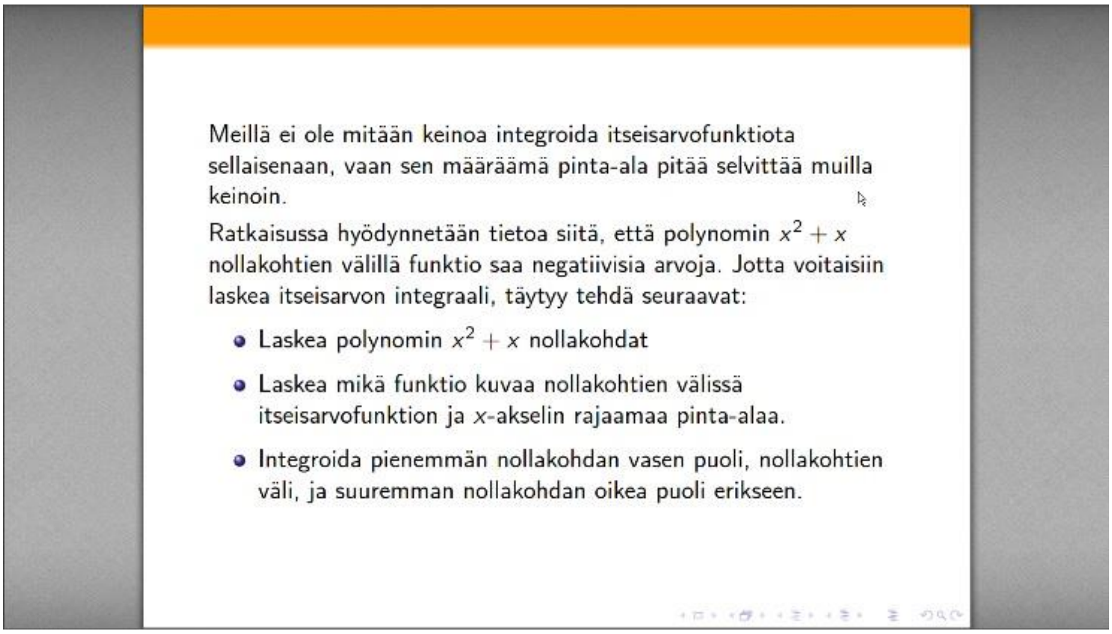

Figure 4.7: Theory can be presented easily, and the end result looks good.

Mathematics videos benefit most from this style of work, since latex is already very well suited for mathematics, and the mouse cursor can be used to highlight certain content in the slides at the pace of the narrator. This is demonstrated in Figure 4.8.

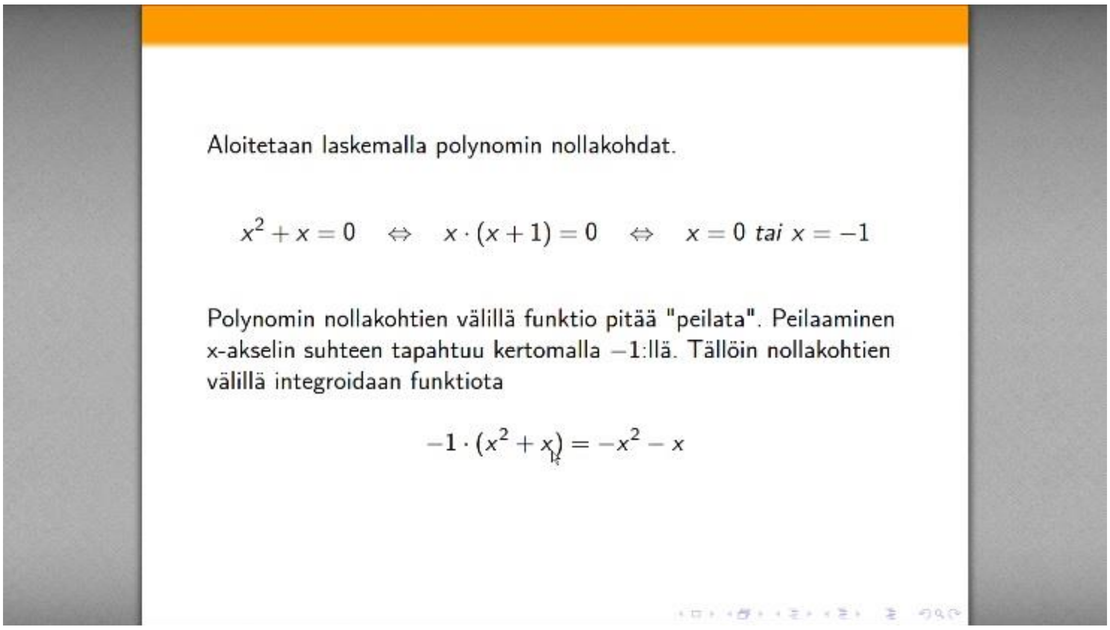

Figure 4.8: Use of the mouse cursor to highlight certain content.

After the content has been reviewed, it is time to close out the video and provide continuation for the students. In these videos, this is done by telling them to work on the Remedial Instruction problems related to the video, by wishing them good luck in the exercises, as well as informing them about the possibility of asking questions on the Echo360 platform.

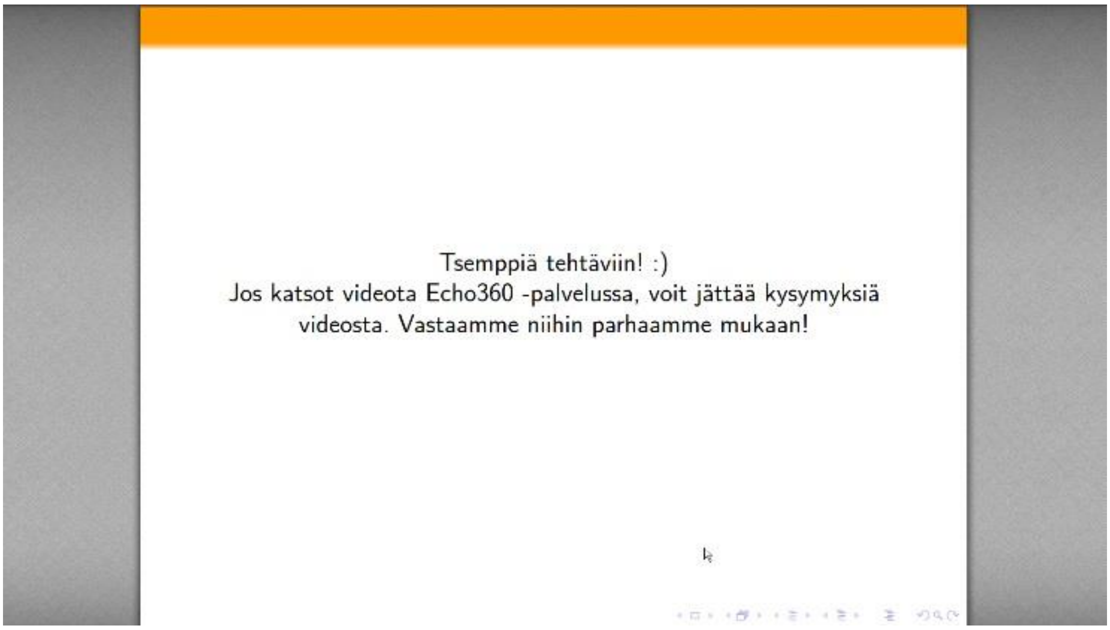

Figure 4.9: Use of the mouse cursor to highlight certain content.

Creating the videos by following the steps presented in the FEV was not only succesful, it was also a valuable lesson for the author. The structure of the videos forces the creator to focus on the different problems associated with learning any given topic. This can ultimately lead to better teaching overall, as the teacher can come up with new strategies that can combat these difficulties. These strategies can then pass on to everyday work. In this way, the videos create value for both parties, the teacher and the student as well.

4.3 Comparison Between BST, Learner Profiles, Questionaire and EM1 Exam Results

In this section, the results of the Basic Skills Test, the Remedial Instruction questionaire, the first Engineering Mathematics 1 and Mathematics 1 exams and the students' learner profiles will be studied and analyzed. The analysis will be done in such a way that the results could be used in finding a answers to the research questions of this thesis. Namely, research questions 2, 3 and 4 will be addressed.

4.3.1 Basic Skills Test Results

The Basic Skills Test was organized in 2015 as explained in Section 2.2. In total, 663 students took part in the test. These students scored points ranging from 0 to 16. The results are shown in Figure 4.10.

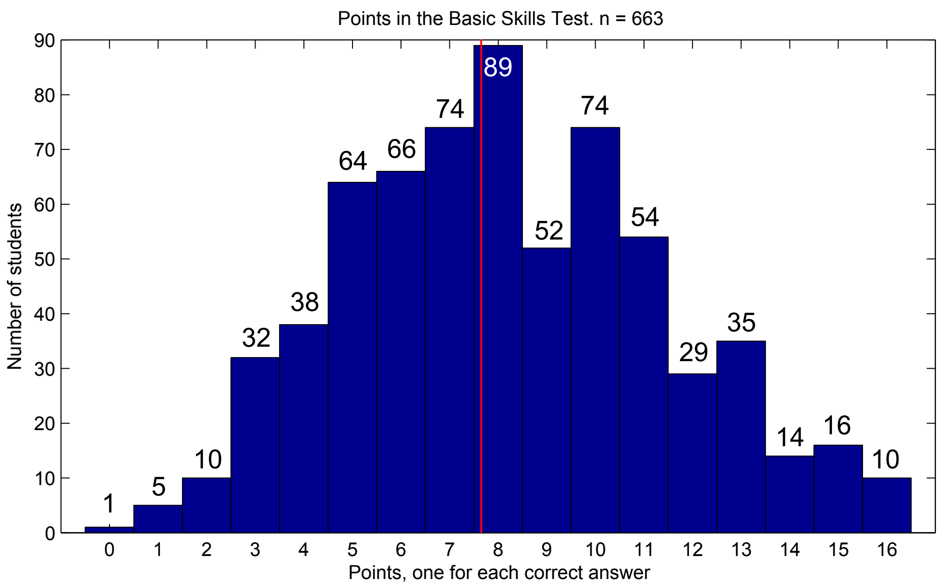

Figure 4.10: Points for the 663 students who participated in the Basic Skills Test. Maximum amount of points was 16, minimum 0. The mean of the points (red line) was 8,175 with a standard deviation of 3,2684 and standard error of 0,1269.

According to the point distribution of the Basic Skills Test, the test is quite well balanced in terms of difficulty. It is not too difficult nor too easy, and most students can complete half of the problems.

When inspected, the points of the Basic Skills Test seem to lie in a normal distribution, with the peak at eight points. The mean is at 8,175 points, which is a little over half. This means that when tested this way, without calculators or other tools such as formula books, on average students can solve half of the problems that they could have encountered in high school. This could indicate that students rely on different types of tools when solving mathematics problems, and it will be studied later what these kinds of tools exactly are. Also, the idea of bringing educational videos to this toolbox is studied.

It should be noted that in total 169 people were directed to or participated voluntarily in the Remedial Instruction based on their result in the Basic Skills Test. This includes students from both courses Engineering Mathematics 1 and Mathematics 1. EM1 had a passing level of six points, where as in Mathematics 1 the limit was a bit higher at eight. Therefore, some students who had six or seven points who would normally have passed the BST were still directed to the Remedial Instruction.

Students who participated in the Remedial Instruction

As discussed before, students with less than six points (EM1) or less than eight points (Mathematics 1) were directed to the Remedial Instruction. However, the Remedial Instruction is free to all students, and thus there were some students who had passed the BST but still decided to take part in remedial mathematics. The results of remedial instructees for the BST are shown in Figure 4.11.

The rest of this thesis focuses mostly on these 169 students and their activity during the Remedial Instruction. With such a low score in the Basic Skills Test, it will be interesting to see what kinds of tools they have reported to have used, and to see, how they view the Remedial Instruction as a support tool for learning mathematics. Clearly, if they can only complete a maximum of five out of sixteen high school mathematics questions, they have a lot of work ahead of them to catch up to their peers.

4.3.2 Learner Profiles

As described in Chapter 2, at the start of the Basic Skills Test, students answer a question about their attitudes and motivation in studying mathematics. In Figure 4.12, the answers for all students are shown. In addition, the number of students from each learner profile that was directed to the Remedial Instruction is shown in darker color.

In total, 33,3 % of surface oriented learners, 30,6 % of peer learners, 33,3 % of students needing support, 21,3 % of independent learners and 15,6 % of skillful

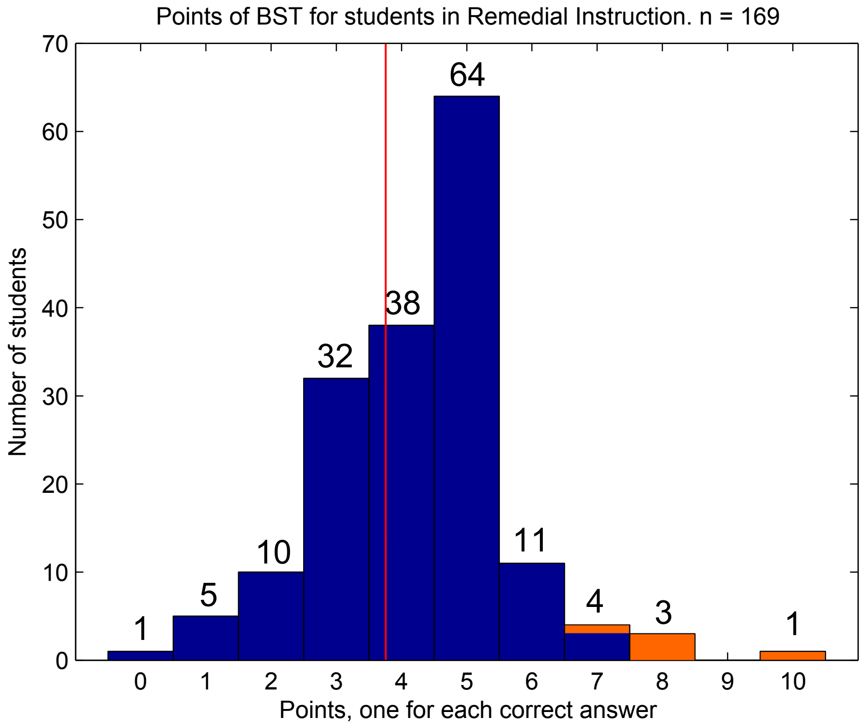

Figure 4.11: Points for the 169 students in Remedial Instruction who participated in the Basic Skills Test. EM1 students needed six points to pass, Mathematics 1 students eight. Volunteers (in orange) could also complete the Remedial Instruction. The mean (red line) of points was 4,2663 with a standard deviation of 1,14413 and standard error of 0,1109.

students were directed to the Remedial Instruction.

The data available allowed for a more in-depth look at the different learning profiles. Below, in Table 4.1, the average BST points for each learner profile are given.

Table 4.1: Basic Skills Test average points their standard deviation for students in Remedial Instruction of different learner profiles.

Learner profile	S.O.L.	Peer L.	S.N.S.	Ind. L.	Skill. St.
n	36	71	13	17	32
Avg in BST	4,056	4,056	4,230	4,059	5,094
STDev	1,603	1,308	1,641	1,249	1,329

While the sample size for students needing support is the lowest, their average points are the highest, although they also have the highest deviation between the scores. Skillful students have the highest BST average, which is partly explained by the fact that out of the five students that voluntarily participated in the Remedial Instruction, four had chosen the skillful student -option.

Knowing the amounts of different types of learners in the Remedial Instruction can provide some insight to later parts of this thesis. Especially, additional analysis can be done regarding some use of tools and their connection to learner profiles.

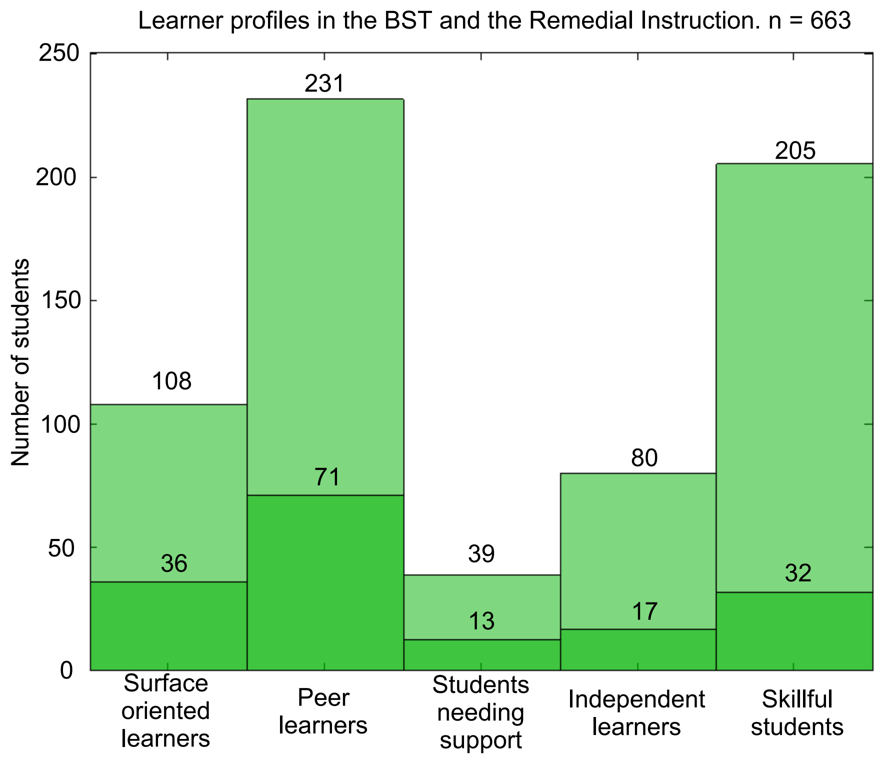

Figure 4.12: The amount of students in each learner profile that participated in the Basic Skills Test (light green) and the Remedial Instruction (green).

Students' answers to the learner profile question can also be thought of as a representation of their attitude towards mathematics. Most students who took part in the Remedial Instruction reported being peer learners, which means that they "enjoy doing mathematics together with other students" and "feel that mathematics is necessary". The fact that these students fail the BST but still find mathematics useful would implicate that they will find the Remedial Instruction a very welcome addition to their studies.

4.3.3 Questionaire Results

In this section the questionaire answers are analyzed. Overall, the questionaire had a total of 69 answers submitted. Out of the 169 people who participated in the Remedial Instruction, this is approximately 40,8%. Answering to the questionaire was not mandatory in order to pass the Remedial Instruction, but there was an incentive to answering (movie ticket raffle). In this section, the answers to the questionaires will be presented. The questionaire was answered by 14 surface oriented learners, 26 peer learners, 6 students needing support, 7 independent learners and 16 skillful students. Detailed tables of the answers are shown in Appendix B.

Students who watched videos

Out of the students who answered the questionaire, 11 had watched the videos. This is 6,5% of the students who participated in the Remedial Instruction. This percentage amount has been very common for any video material in TUT's Echo360 experience. Some explanation to the amount of views will be discussed later.

Of the students that watched the videos, seven were peer leaners, three were surface oriented learners, and one was a skillful student. When looking at the answers, the answerers' attitudes can be considered in relation with these learner profiles.

The first question for those who watched the videos was about the help that the Remedial Instruction provided for the students. The answers are shown in Figure 4.13.

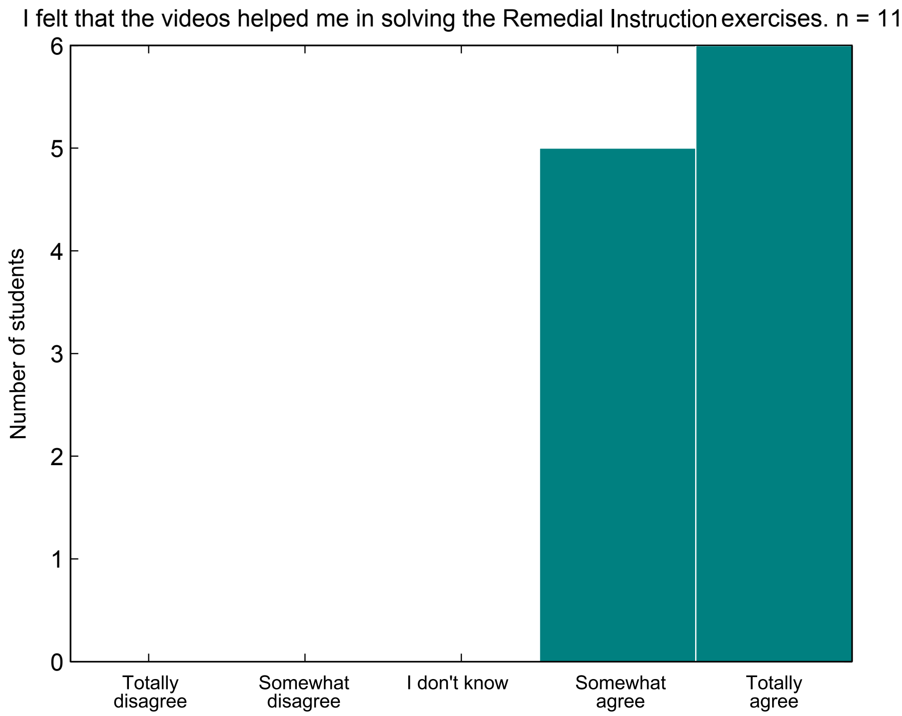

Figure 4.13: Answers to questionaire question 3 on the Likert scale.

As can be seen, all answers to first question are very positive. This would mean that those who watched the videos were very pleased with the effect that they had on their success in the Remedial Instruction. The second question was about how clearly the content was presented in the videos. This is very important according to the Framework for Educational Videos presented earlier. The answers are presented in Figure 4.14.

Here the same note can be made as in the first question, and that is that the answers are all positive. Students seem to find that the Beamer and Camtasia setup provides a clear platform for the teacher presenting the content. Also, it

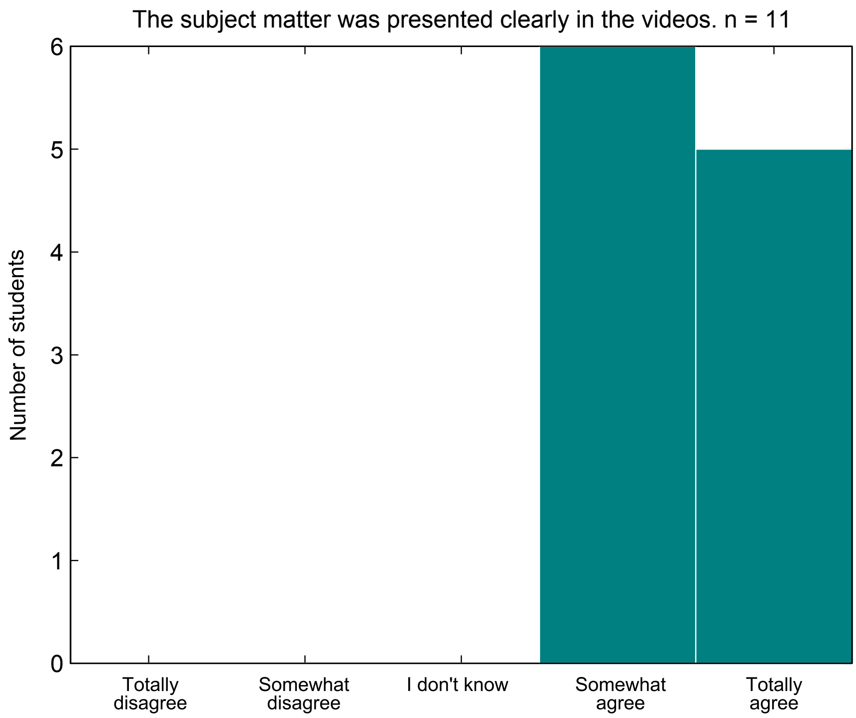

Figure 4.14: Answers to questionaire question 4 on the Likert scale.

would seem that the scripting has been very successful, since the topics have been presented clearly.

Next question was about video quality. Quality is important when catching the students' attention, and a good quality video will also be able to maintain that attention until the end. Answers to the video quality question are presented in Figure 4.15.

There is one answer on the somewhat disagree, which is understandable. The affordable studio setup produced at least some mouse clicking sound, and the conversational style used in the videos was a bit uncomfortable at start. However, the majority of people approved of the sound and picture quality, which is good.

One of the most important aspects of successful multimedia is of course their availability. If students do not know where to look for the videos, then they will not watch them. Not knowing about videos or not finding them could also be an important reason for why such a low number of students have watched the videos. The answers to question 6 are presented in Figure 4.16.

According to those students who had watched the videos, it would seem that the fear of the videos being unavailable was null. This fear can be further analyzed when asking those students, who didn't watch the videos, if they thought that the videos were hard to find.

Next question was about video duration. Duration is an important part of any educational video due to the fact that videos should be created so that they are of

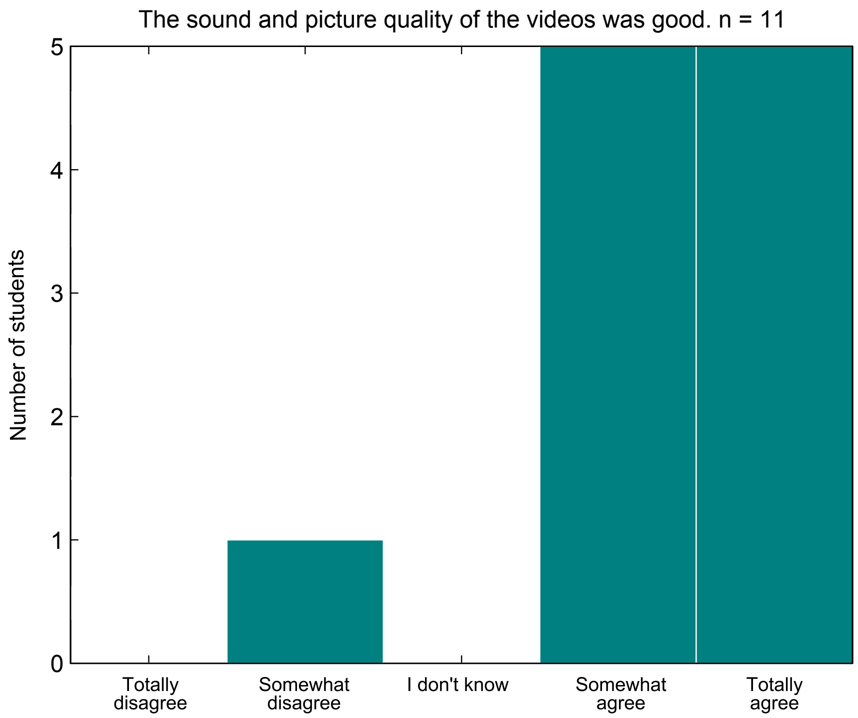

Figure 4.15: Answers to questionaire question 5 on the Likert scale.

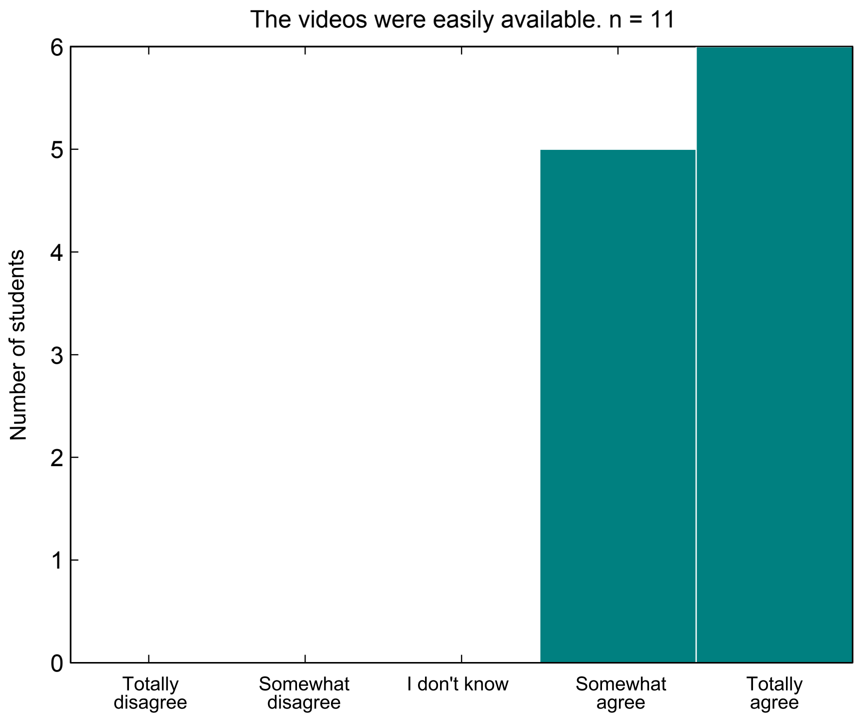

Figure 4.16: Answers to questionaire question 6 on the Likert scale.

digestable size. Answers to the question about duration are given in Figure 4.17.

It would seem that students have found the videos to be of suitable length. This result was however very easy to anticipate, since duration is - after all - one of the most important factors of educational success. Too short, and the videos will

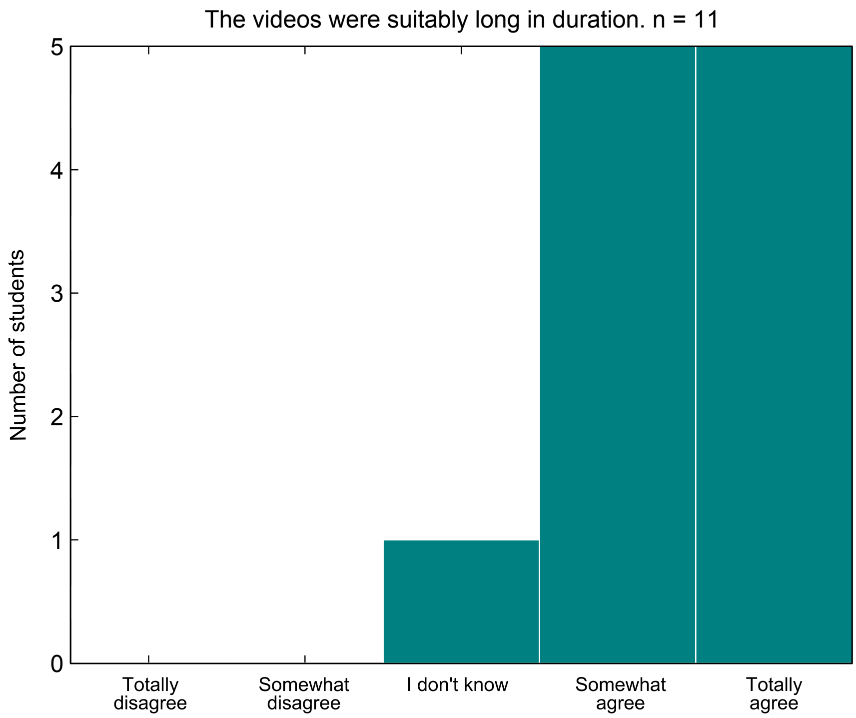

Figure 4.17: Answers to questionaire question 7 on the Likert scale.

not teach anything, too long, and the concentration of the student will falter, and nothing will be learned.

All in all, it would seem that those students who watched the Remedial Instruction videos have been very pleased with them. This is good news when moving forward with the analysis, and it will be interesting to look into what kinds of students have been active in using these videos.

Students who didn't watch videos

As there were 69 answers to the questionaire, the number of students who did not watch Remedial Instruction videos is 58. As was discussed previously, the questions for these students aim to understand why they hadn't watched the videos, and in this way, their answers could be analyzed and possible explanations could be found for lack of use of this educational multimedia.

The answers to the first question for students who had not watched Remedial Instruction videos are shown in Figure 4.18.

The first pitfall for educational multimedia is its availability. If students are unable to find and watch any given videos, then it is highly unlikely that they will. Also, as the Remedial Instruction is done online and the information regarding it is stored on the university online learning platforms, students might find it difficult to use these new tools. The most important task for a teacher is to make the videos easy to find and to inform the students where to find them.

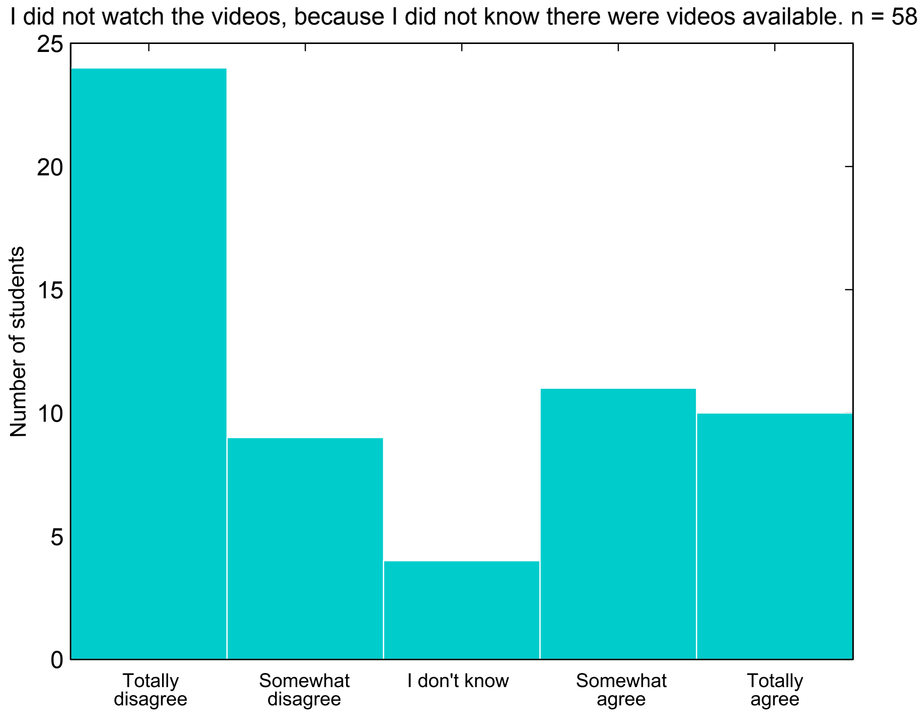

Figure 4.18: Answers to questionaire question 8 on the Likert scale.

As the Figure shows, opinions on whether or not the videos were marketed successfully are mixed. At this point when getting a result like this, it is apparent that for those that disagree on availability, it should be examined where these students have agreed on the causes for not watching videos. This will be done later. Most students disagree on the videos not being available, but many are also in agreement with this statement. This means that it would be better to have the videos even more readily available.

Following availability, it was tested if the students hadn't watched the videos because they already knew the topic at hand. There are many reasons why a student would score low in the Basic Skills Test, and scoring low in it does not mean that they are not good at mathematics. If many students agreed on the claim provided here, then they could be a part of this group: then ones who know mathematics, but still fail the BST for some reason. Answers to the questionaire question 9 are shown in Figure 4.19.

The result shows that the students are quite split at this claim. They are however stronger in their opinions when disagreeing. Somewhat agreeing to this claim can be seen as a reason for not taking the time and watching through the videos. It should also be noted that this result does not mean that half of the students do not know the topic. Thus there might be other reasons for not watching the videos.

The next result will be very clear as the claim is straightforward. The stu-

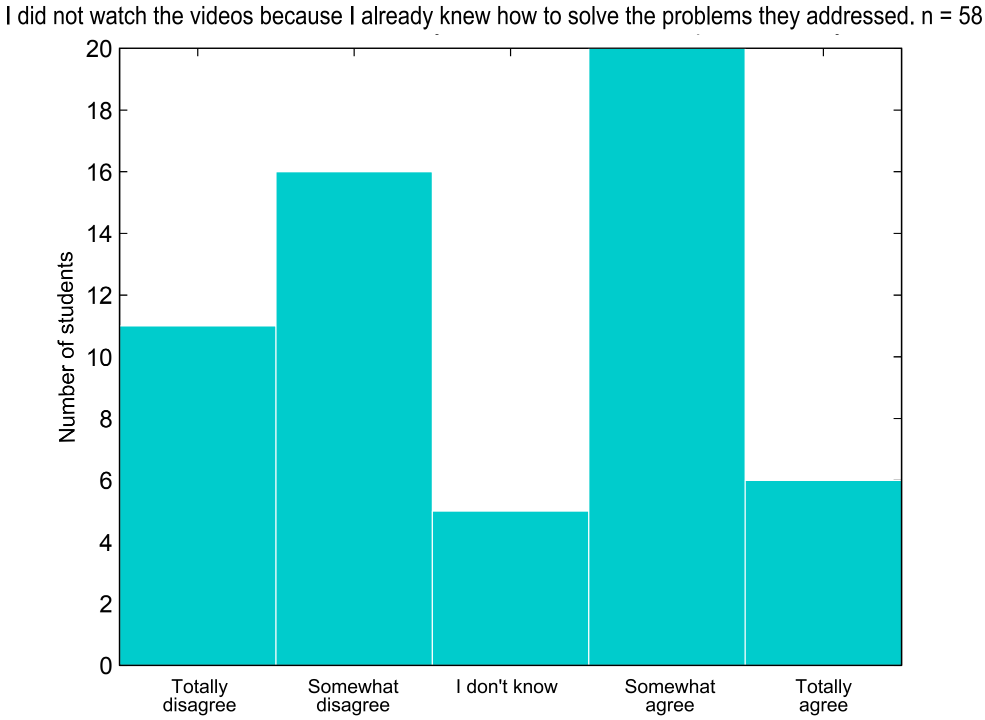

Figure 4.19: Answers to questionaire question 9 on the Likert scale.

dents were asked if they simply dislike educational videos and for this reason didn't watch the videos. Since modern students usually have a lot of experience watching YouTube and other such media, they might have a bias either for or against using this familiar method in teaching. The results are shown in Figure 4.20.

Majority of students disagree with this claim. Some are in somewhat agreement and just few have a strong dislike towards videos. This result is encouraging in the sense that educational videos might have a future since there is no strong hatred towards them.

The aim of the questions for these students is to find out why they haven't watched the videos, so a very important aspect is to ask if they used some other mathmematical tools when working on the problems. If they got the help they needed elsewhere, then the videos would not be necessary for them. The results for this question are shown in Figure 4.21.

The result is very clear. Most students agree that they did not watch the videos because they used other tools, and it could be argued that for this reason, the videos didn't become very popular. This result is encouraging and disheartening at the same time: on the other hand, the result means that students would probably enjoy using the videos if they didn't have other tools available. On the other hand though, the fact that students have a lot of tools at their disposal might make educational videos kind of useless and force them to compete in a very crowded field. However, the results for those students who had watched the videos are so successful, that

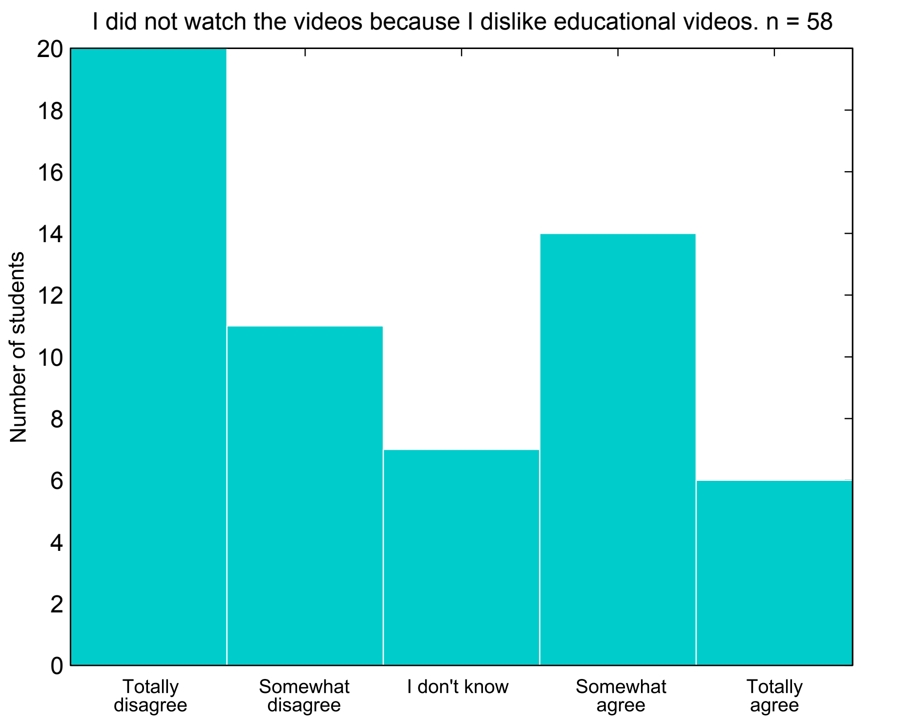

Figure 4.20: Answers to questionaire question 10 on the Likert scale.

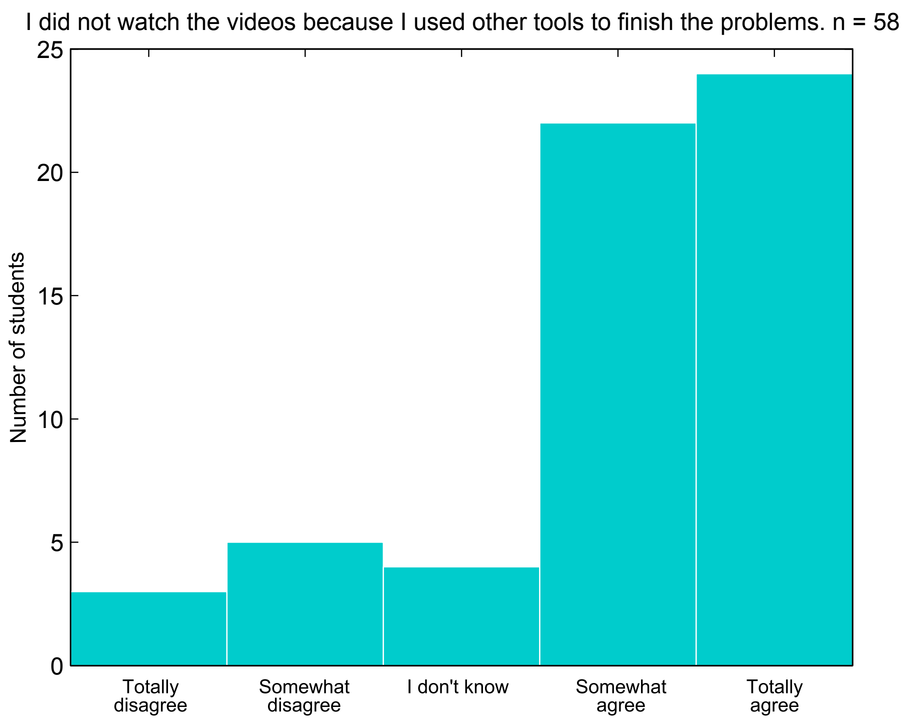

Figure 4.21: Answers to questionaire question 11 on the Likert scale.

this fear is almost completely nullified.

The open question, question number 12, did not gather that many answers. All of the answers that were given were as follows:

- "I was not able to log into the system."
- "I was in a hurry to complete the Instruction."
- "I only noticed one video."
- "I had successfully completed the Basic Skills Test."

These are all reasonable reasons to not have watched the videos, but they are also quite well handled by the claims above. Thus, there is no real reason to think that there would have been any other critical reason for students to not watch the videos. It would seem that the most important reason to not watch the videos was the use of other tools to finish the Remedial Instruction exercises. This will be looked into in more detail in a later section.

Student's use of time during the Remedial Instruction

Two questionaire questions delved into the students' use of time during the Remedial Instruction. The answers are shown in Figures 4.22 and 4.23.

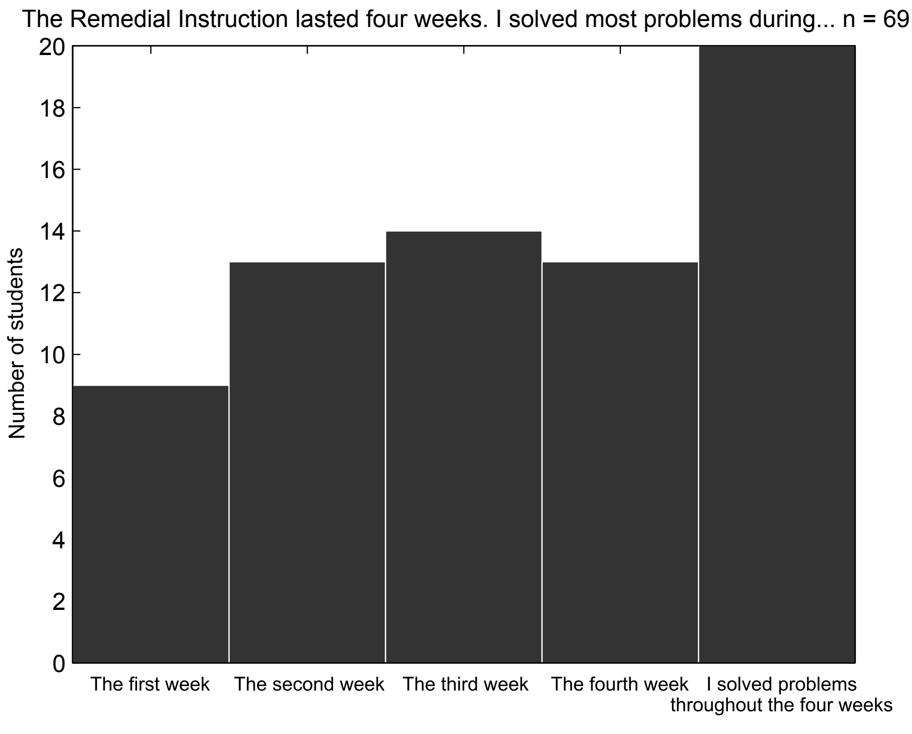

Figure 4.22: Answers to questionaire question 13.

It would seem that students have evenly spaced their main working time between the four different weeks. Also, the majority of students reported to have worked on the problems during the whole time, which is ideal in order to carefully go through the problems and not overload themselves with other school work. The use of time is also quite well balanced out, with the main spike in time spent at 5 to 10 hours. Some have reported over 15 hours used on the problems, but the amount is so low, that it really isn't a problem.

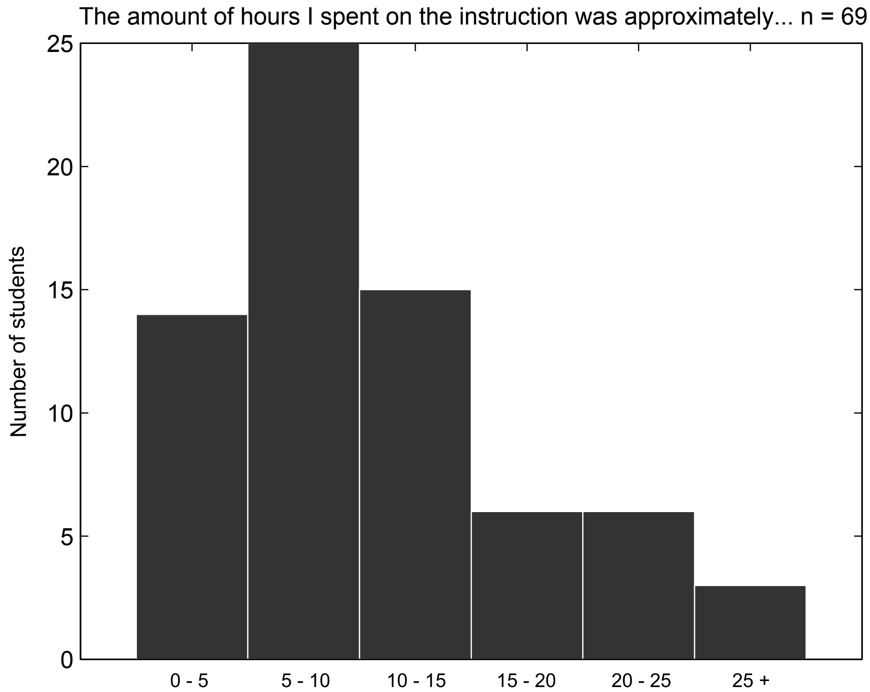

Figure 4.23: Answers to questionaire question 14.

Use of tools in the Remedial Instruction

In order to answer the second research question in this thesis, "What kinds of tools are used by students to complete the Remedial Instruction?", the students were also asked to specify which tools they used while solving the Remedial Instruction problems. The possible tools that students could select from (multiple choices were allowed) were:

- **Pen & Paper:** Self-explanatory. Mathematics is best suited for pen and paper work.
- **Wolfram Alpha:** The web-based knowledge tool that can be found online at www.wolframalpha.com.
- **CAS Calculator:** The new CAS calculators were adopted in wide use all over Finnish highschools a few years ago. The students who participated in the 2015 Remedial Instruction had all used CAS throughout their high school studies.
- **Function Calculator:** The more classic function calculator is often allowed in exams at the university due to its simplicity.
- **Highschool books:** Used by students throughout high school. There are several publishers in Finland that offer high school mathematics books.
- **Remedial Instruction Teaching Material:** Available on the Math-Bridge platform used for the Remedial Instruction, this online library contains similar

information as high school mathematics books.

- **Remedial Instruction Model Answers:** After trying to solve a given problem, students are able to look at a model answer of the problem. They can then attempt the problem with new numerical values.
- **Remedial Instruction Videos:** The videos created for this thesis that were available from a hyperlink on the Remedial Instruction page as well as on the Moodle platform that directed to the Remedial Instruction.

Students reported their use of these tools as can be seen in Figure 4.24 below.

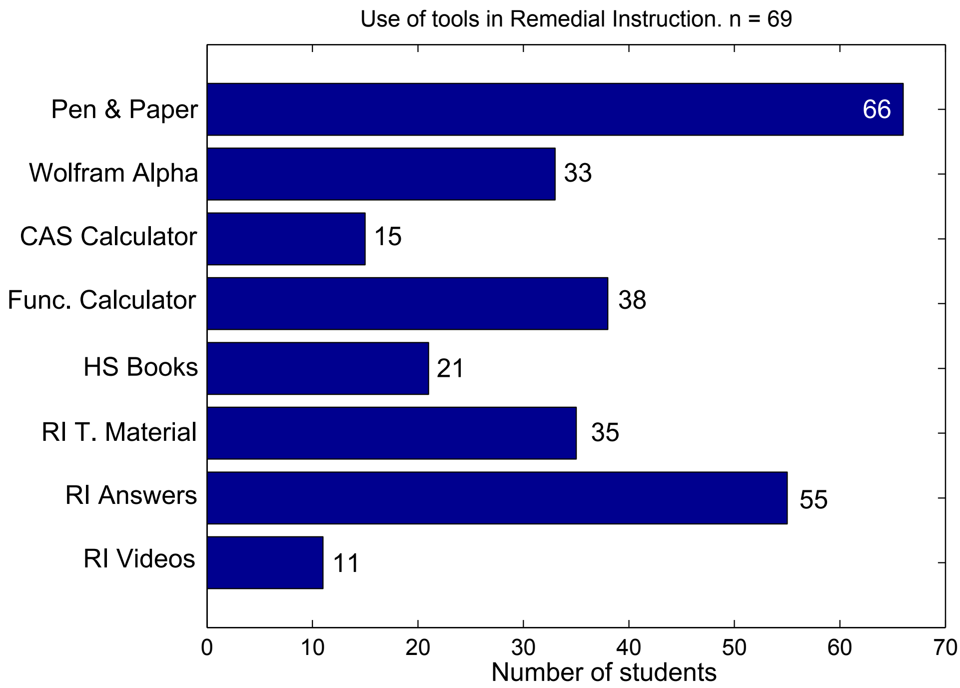

Figure 4.24: The reported use of tools for students in the Remedial Instruction.

The greatest surprise to be found from this data is the low use of the CAS calculator. Few students have reported its use, even if it is an important tool in today's high school mathematics. However, similar calculations can be done using Wolfram Alpha, and in a sense, it could be argued that students are using one or the other. Adding together the users of CAS and WA would bring the users of some kind of CAS system to 48. This number would be third highest in the data.

Other commonly used tools besides pen and paper and Wolfram Alpha are the Remedial Instruction teaching material as well as the model answers presented with the problems. This could indicate that students really like the fact that they can study the teaching material and the model answers at the same time as they are solving the exercise problems. When further developing the Remedial Instruction, this information should be kept in mind.

Overall user experience in the Remedial Instruction

The questionaire ended with five questions about the user experience in the Remedial Instruction. The first question was about difficulty level. If students find a given task unreasonably difficult after completing it, then the problems should be looked at. The answers to the question about Remedial Instruction difficulty are shown in Figure 4.25.

Most students agree on this question. Some have slight disagreement, but the overall result might implicate that the Instruction is of reasonable difficulty, and that no major changes are necessary in this regard.

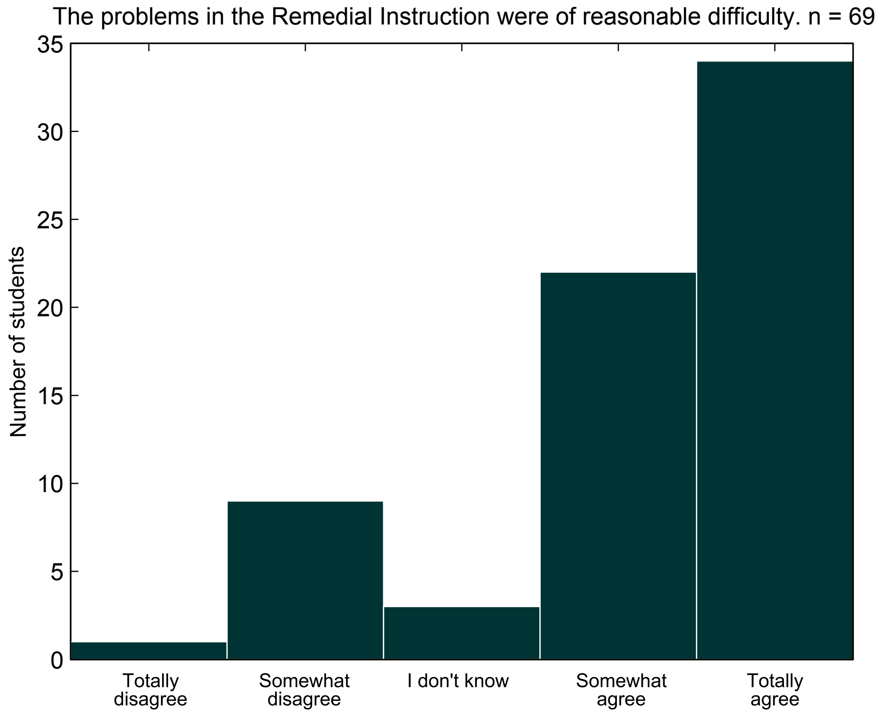

Figure 4.25: Answers to questionaire question 16 on the Likert scale.

Next, focus is directed to the benefit that students experienced when completing the Remedial Instruction. The added benefit was measured for two separate questions: the remedial effect of the Instruction for high school mathematics, and the aid that the students got from the Instruction for their first mathematics course at TUT, Engineering Mathematics 1. For high school remedial effect the results are shown in Figure 4.26.

It is quite clear that the Remedial Instruction has been very successful at what it's trying to accomplish. Almost all students agree that they gained benefit from the Instruction. This is a nice result overall, and shows that the Instruction is an effective tool at the task it was designed to accomplish. But how well does the benefit carry over to Engineering Mathematics 1? The students' answers are shown in Figure 4.27, and it can be said that the trend continues. The result is not as much

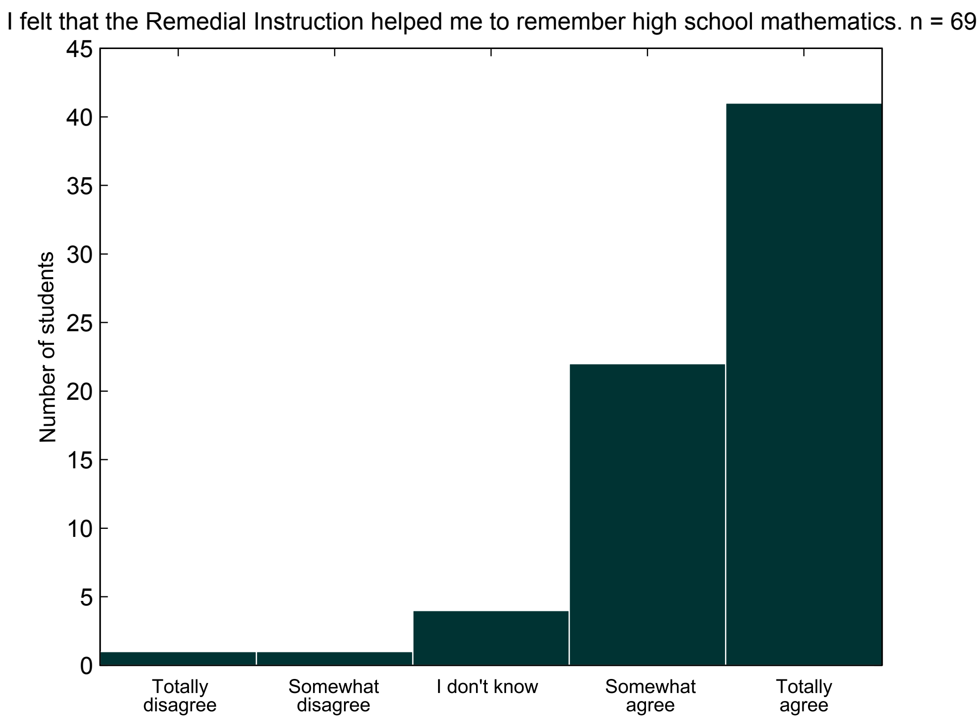

Figure 4.26: Answers to questionaire question 17 on the Likert scale.

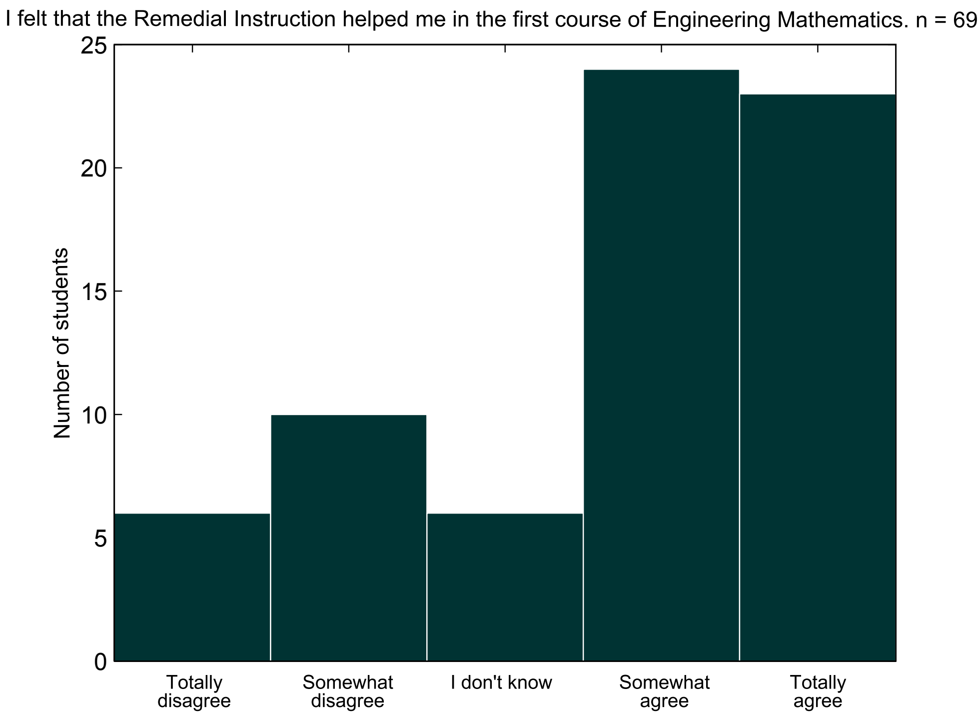

Figure 4.27: Answers to questionaire question 18 on the Likert scale.

a landslide as the previous one, but still, most students agree that the Remedial Instruction has helped them in the start of their mathematics studies. Oftentimes students might have difficulties linking their previously learned mathematics with the new material that they study. This surface-oriented style of learning is not very productive at all, but might explain why a few people disagree with the claim.

Next, the teamwork of students was studied. Students were asked if they had collaborated on the exercise problems. At TUT, students are encouraged to network and work together with their peers in order to achieve better learning results. The answers to the question about teamwork are shown in Figure 4.28.

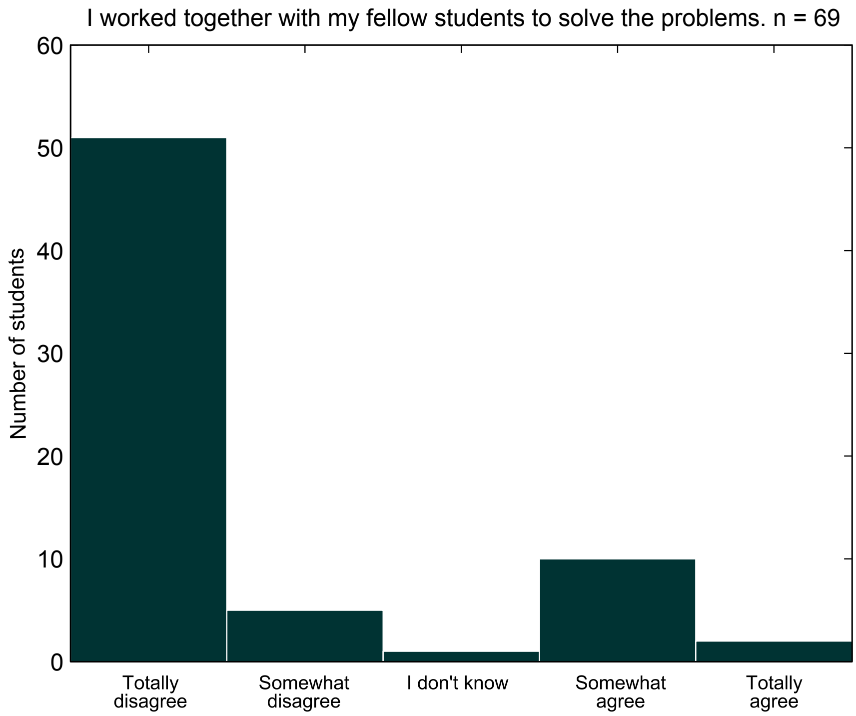

Figure 4.28: Answers to questionaire question 19 on the Likert scale.

The result is very clear. Students do not work in teams to solve the problems. This could be due to the instruction being done on computers, and working on a computer might be seen as a solitary task. Also, the fact that each student has personalized problems could play a role here. It would be better if students did more teamwork, as they could also teach each other.

Finally, a question was asked about students' feeling of getting help if necessary. There are designated teachers at the department whose contact information are available for students. If they happen to need technical or mathematical support, they can contact these persons. Students were asked if they felt that help was available to them. The answers are shown in Figure 4.29.

Most students agree on this statement, but a very big part of students have also chosen "I don't know". The question might have been poorly constructed, or perhaps students have not thought about this issue at all. It would still seem that no actions are necessary in the future regarding technical or other support.

Overall, the questionaire collected a good amount of answers. Also, the results from these questions would show that those students who watched the Remedial

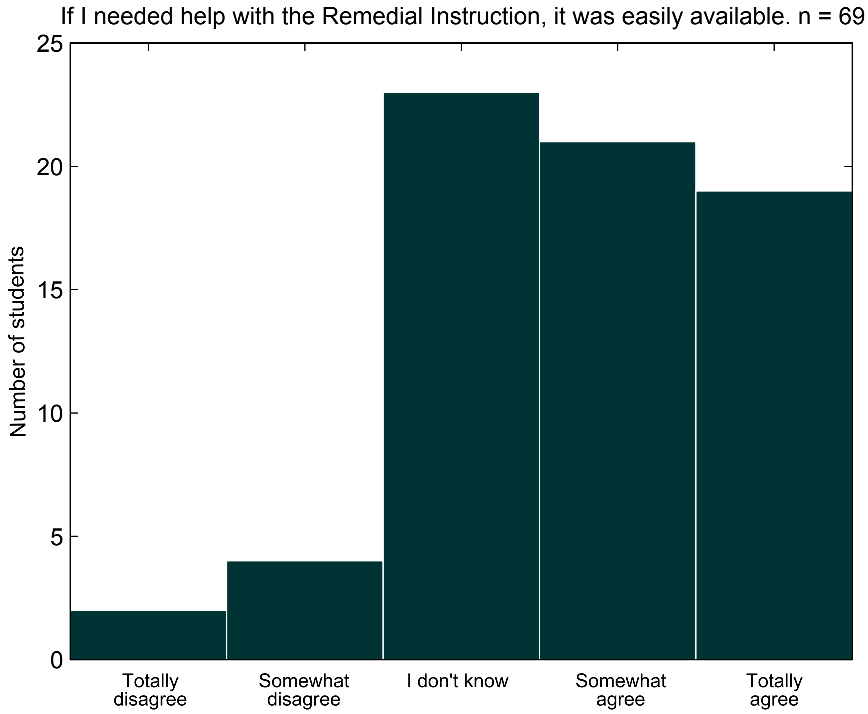

Figure 4.29: Answers to questionaire question 20 on the Likert scale.

Instruction videos really enjoyed them, and those that did not, have used other tools instead of videos to finish their exercises. This can be seen as a positive result in favor of using videos as an educational tool in the Remedial Instruction in the future.

4.3.4 EM1 and M1 Exam Results

To measure the effectiveness of the Remedial Instruction, the students' exam results were also studied. The overall results of Engineering Mathematics 1 and Mathematics 1 courses for students in Remedial Instruction are shown in Figure 4.30. If the student has not yet participated in an exam, their grade is zero.

The grades are heavily biased towards the low end. Most students have not passed the exam, and a great majority of 71,6 % had scored a grade lower than 3, which would be equal to "good". Out of the eleven students that had watched the Remedial Instruction videos, six had failed the exam, while one student got a one, and four got a three. However, the result could be a lot worse without the Remedial Instruction.

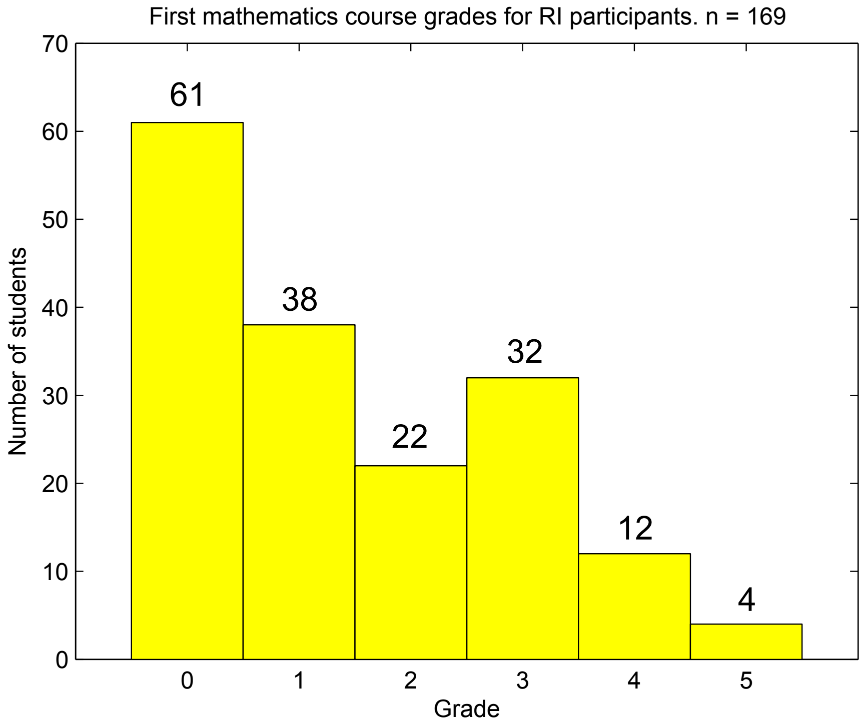

Figure 4.30: Grades for the first mathematics course Engineering Mathematics 1 or Mathematics 1 for RI participants. A grade of zero means that the course has not been passed. The mean is 1,456 with a standard deviation of 1,440 and standard error of 0,111.

The exam results can also be looked at from the learner profile viewpoint. In Figure 4.31, the results of the first exam are shown for each learner profile separately. The results are also given in Table 4.2. From the graph it is quite easy to see that for all other groups other than skillful students, the results are heavily weighted on the zero and one grades. As a result, the overall trend is not surprising, but the amount of failed exams is alarmingly high. On the other hand, this result could indicate that failing the Basic Skills Test is a sign of future problems in university mathematics. If nothing was done to help these students, then their results could be even worse.

Table 4.2: Different grades for different learner profiles in the RI. Numbers are in percentages and describe the number of students divided by the total population of 169. There is a rounding error of 0,1 % in the summed lines.

Learner profile	S.O.L.	Peer L.	S.N.S.	Ind. L.	Skill. St.	Σ
Grade 0	10,1	16,0	3,5	3,5	3,0	36,1
Grade 1	4,1	12,4	0	4,1	1,8	22,4
Grade 2	1,8	4,1	1,8	1,2	4,1	13,0
Grade 3	4,7	7,1	1,8	0,6	4,7	18,9
Grade 4	0	1,8	0,6	0,6	4,1	7,1
Grade 5	0,6	0,6	0	0	1,2	2,4
Σ	21,3	42,0	7,7	10,2	18,9	100 %

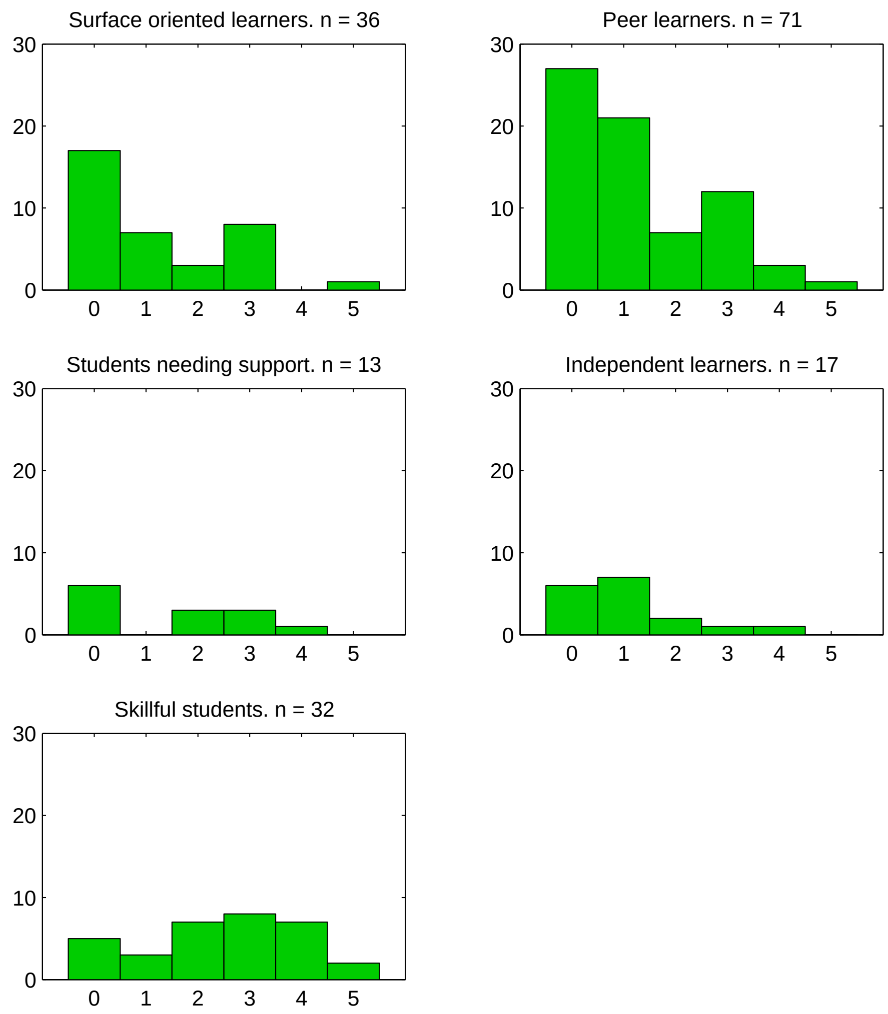

Figure 4.31: Grades for the first mathematics course Engineering Mathematics 1 or Mathematics 1 for each learner profile in the Remedial Instruction.

In order to further solidify the effectiveness of the Basic Skills Test, the results of the BST can be compared to the average grades in the first mathematics exams. If the BST correctly predicts success in mathematics, then even for the Remedial Instruction students, the graph should be a rising line. This graph can be been in Figure 4.32.

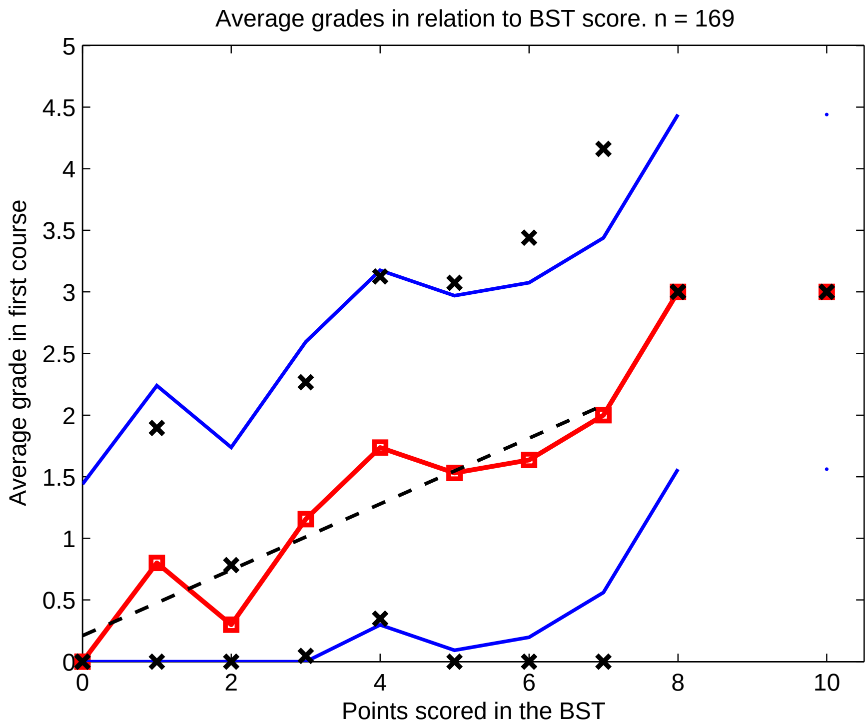

Figure 4.32: A graph representing the average grade in the first course exam for each BST score (in red). Blue lines show the standard deviation for the whole population, and the black crosses implicate the standard deviation for that point population. Data points with BST score higher than seven points could be disregarded here since these are students who took part in the Remedial Instruction voluntarily. There were no students in the Remedial Instruction with 9 BST points.

As can be seen, the graph is a rising line as expected. In order to confirm correlation between success in the BST and the first course exam, a least squares line was fitted to the data, and the correlation coefficient for the data was calculated. The Remedial Instruction volunteers were exluded from this test. The line fit is presented in Figure 4.32 as a black dotted line, and the correlation coefficient r_{XY} for the data is 0,213. Testing this correlation with t gives

$$t = \frac{0{,}213 \cdot \sqrt{165 - 2}}{\sqrt{1 - 0{,}213^2}} = 2{,}783,$$

which is above the 1 % critical line of 2,576 (163 degrees of freedom) [17]. Thus, the correlation is statistically significant, and this is another confirmation that the Basic Skills Test is an effective tool at identifying those students that will have difficulties in their mathematics studies.

Overall, the exam results are somewhat bleak. It could be said that students in the Remedial Instruction need all the help that they can get. If the results of the BST are low, it is very likely that the results of the first course's exams will follow suite.

4.3.5 Additional Analysis and Discussion

As the previous sections have shown, not all research questions have yet been answered. For this reason it is important to do some additional analysis and try to find if at least partial answers could be provided. This section aims to do this by conducting a few special studies with the data at hand.

Students that could gain most from educational videos

In order to find answers to the second part of the second research question, "is it possible to identify the type of student that would gain most from this type of multimedia", a small sample study can be conducted on those who answered the Remedial Instruction Questionaire. The aim is to compare their BST score, learner profile and exam grades, and if similarities can be found, then this could indicate the type of student that could gain most from educational videos. The actual study of this will of course be left to future studies due to the low sample size, but it is possible to achieve some direction from which to start.

The students that watched the Remedial Instruction videos and their scores in the BST, first course exam as well as their learner profile are tabled in Table 4.3.

Table 4.3: Learner profiles, BST scores, 1st exam grades and grade comparisons for students that answered the Remedial Instruction questionaire and had watched the videos. Grade for the BST was the following: less than six points gives 0, six to eight points gives 1, nine to ten points gives 2, eleven to twelve points gives 3, 13 to 14 points gives 4, 15 to 16 points gives 5.

Learner profile	BST Score	BST Grade	1st exam grade	Grade difference
Peer Learner	3	0	1	+1
Peer Learner	3	0	0	0
Peer Learner	3	0	0	0
Peer Learner	5	0	3	+3
Peer Learner	5	0	Not available	?
Peer Learner	2	0	0	0
Surface Oriented	3	0	3	+3
Surface Oriented	5	0	0	0
Surface Oriented	4	0	0	0
Surface Oriented	3	0	1	+1
Skillful	8	1	3	+2

The sample size is so small that it is very difficult to make any accurate predictions for the student type that would gain most from educational videos. However, there are some reasonable assumptions that can be made: skillful students will gain a lot from any tool that they use. Then, it is only a matter of preference if they choose to use the videos or not. In addition, the first groups that could be directed to the videos are surface oriented learners and peer learners. This is due to the fact that these groups are both at quite a high risk of getting very poor grades even if they have participated in the Remedial Instruction (see Figure 4.31 and Table 4.2). The type of educational videos presented in this thesis could be considered one tool to be used to improve the results of these students.

Number of different tools used by learner type

The average use of tools for each learner type was also studied. The number of different tools used could provide some information about the nature of using tools in the Remedial Instruction. Multiple tools could or could not lead to better learning results, and thus it would be interesting to look at two things: if using multiple tools leads to better results in the Remedial Instruction and in exams, and if certain learner profiles have a tendency to use more tools than others. The averages were calculated from the 69 students that answered the Remedial Instruction questionaire and are shown in Table 4.4.

Table 4.4: Average number of tools used for each learner profile. Data was calculated from the students that participated in the Remedial Instruction and answered the questionaire.

Learner profile	S.O.L.	Peer L.	S.N.S.	Ind. L.	Skill. St.
n	14	26	6	7	16
No. tools used avg.	4,714	4,038	4,000	3,571	3,250
St. Deviation	1,139	1,661	0,632	0,9759	1,238
St. Error	0,304	0,328	0,258	0,369	0,310

The analysis shows that independent learners and skillful students tend to report to have used less different tools than other learner types. It could also be thought of as a sign of security in mathematics: if a student does not find help from a given tool, they will use the next one, then another one and so on, until they find a tool that is helpful, and they solve the problem. One possibility is that surface oriented learners might switch between different tools until they find one that will get them to the right solution. In most cases and according to Figure 4.24, pen & paper could be seen as the first tool that students use, followed by the Remedial Instruction model answers. If neither of these help, then they turn to other tools according to varying priorities and tastes.

4.4 Echo360 Analytics Results

The original plan of this thesis was to use the Echo360 analytics tool's data to empirically view the video participation and answer a part of research question 2: "Can it be empirically shown that mathematics videos are effective in supporting students in their completion of the Remedial Instruction?" However, due to reasons discussed later, the overall view amount of the watched videos was extremely low.

In addition to this, the views data provided by teh Echo360 analytics tool is very rich with noise. The platform provides an excel file with rows of the form:

$$Last\,name;\; First\,name;\; Moodle\,user\,ID;\; email;\; 0/1, 0/1, 0/1, ...$$

where the last zero or one indicates if a viewer has watched the video or not. However, this data is very difficult to use due to the following reasons:

- Multiple names that appear on the list are staff members or people that have not participated in the Remedial Instruction.
- Majority of students have left a mark in the log data, but according to the data have not watched any videos.
- The conditions of having either a zero or one in the view chart are not very accurate. Students are appointed a 1 for viewing if they have watched 5 % of the video. However, 5 % does not really cover anything in educational videos. The zeroes and ones are not very usable.
- It is very hard to connect students' Echo360 log data with that of their BST and Remedial Insruction data, since Echo360 does not use student number as ID.

The Echo360 platform offers little in the way of analysis. As no-one used the Echo360 tools presented in Chapter 3, such as taking notes or asking questions, and as the videos themselves contained no quizzes, it can be said that the Echo360 platform is not very well suited for these kinds of short videos. Other platforms such as YouTube could easily provide a more easily accessible place for the videos. Echo360 is best left for lecture and exercise recording.

5. CONCLUSIONS

In this chapter, the theory and findings presented in previous chapters are brought together in order to answer the research questions provided in Chapter 3. After the research questions have been answered, further discussion on the topic as well as plans for future studies are presented.

Research question 1: *What makes a good mathematics educational video, and what is necessary for a teacher to be able to create such multimedia?* The aspects that create quality multimedia in education were presented in Chapter 2 when discussing Mayer's principles of educational multimedia design. The elimination of extraneous processing, managing essential processing and fostering generative processing are all very important tasks of quality multimedia. The existence of all three of them in the remedial mathematics process and their essential linking to Bloom's taxonomy and Gagnè's nine events of instruction were used in creating the Framework for Educational Videos (FEV).

The FEV is proven to be a working tool for teachers, as it was used in creating the videos that were used in the Remedial Instruction of fall 2015. The results of the Remedial Instruction questionaire prove that those students that chose to use the educational videos found them extremely effective in helping them solve the Remedial Instruction problems. Also, the quality and duration of the videos were appreciated. The videos (in Finnish) can be found on the department's YouTube channel `https://www.youtube.com/channel/UC9gZ4VrQQIaYd-irZATtPRQ`. The FEV will hopefully prove to be an effective tool for future video creators, and will definitely need further implementations and iterations in order to be more efficient.

A good mathematics educational video follows the framework presented in Chapter 4. A teacher will find all the things necessary to start creating videos in this thesis (necessary equipment and so on), but only work, iteration and experience can ensure that the videos are effective at what they do. It is also important for any teacher to take into consideration the needs and wishes of their students, as was noted in Chapter 2, Borovik stated that content is more important to students than delivery.

Research question 2: *What kinds of tools are used by students to complete the Remedial Instruction? Can it be empirically shown, that mathematics videos are effective in supporting students in their completion of the Remedial Instruction, and* *if so, is it possible to identify the type of student that would gain most from this type of multimedia?* As was shown in Figure 4.24, students apply various tools to their work in the Remedial Instruction. Also, in the additional analysis of Chapter 3, it was noted that those students that had the most problems in the Basic Skills Test, Remedial Instruction and first course exams had all used a significantly larger number of different tools. The most common way would seem to be using pen & paper first. If solving the problem like this fails, then students will study the Remedial Instruction model answer. If this doesn't help them, they will use some other tool at their disposal, be it Wolfram Alpha, a calculator, videos or books. Overall, it would seem clear that students are very dependent on tools to work efficiently on mathematics. However, there is no evidence which would state that using multiple tools helps in learning mathematics. If Wolfram Alpha and CAS calculators are used to solve the Remedial Instruction problems, almost all of the learning process (the actual problem solving) is skipped altogether.

Due to the low amount of views in the Remedial Instruction videos and the fact that Echo360 is not well suited for these kinds of videos, it is very difficult to empirically state that mathematics videos are effective in supporting students in the Remedial Instruction. However, further analysis showed that peer learners and surface oriented learners were most likely to watch the videos, and these students are the ones that could have the most to gain from watching them. The fact that most students in the instruction were of these two groups of course affects the claim heavily.

The tools used in Remedial Instruction vary quite a lot depending on student learner type, with the most used tools being pen & paper, Remedial Instruction model answers and calculators. The videos created can't be exclusively shown to be effective, but if they were, the most gaining students could be peer and surface oriented learners. It would be interesting to see the effectiveness of the Remedial Instruction if these tools were banned.

Research question 3: *Can the results found in Question 2 be verified by using a questionaire answered by the students taking part in the Remedial Instruction, and if not, what are the differences between the empirical observation and the subjective answers of the questionaire?* As the answer to Question 2 shows, it is difficult to verify that which does not exist. However, the questionaire provided extremely valuable feedback for the videos that were created, and also provided the necessary information to answer Question 2.

All students that watched the videos in the Remedial Instruction reported that they found the videos very useful. The videos had added benefit, good quality, they were easily accessible and their duration was not too long. Also, as discussed in the FEV, the content was presented clearly, and students found that the videos helped them in the Remedial Instruction. According to Table 4.3, some students even had a clear improvement from the BST to the first course exam.

The questionaire also provided data for the overall user experience in the Remedial Instruction. Students gave positive answers to most of the questions, reporting that they found the Remedial Instruction to be useful in helping to remember high school mathematics and that it helped them in the first course of (Engineering) Mathematics. However, almost no-one teamed up with their fellow students to solve the problems. This is very surprising considering that the majority of students reported being peer learners.

While verifying empirical results was not possible, the questionaire provided valuable answers in other parts of the study. One of them was the fact that students that actually watched the Remedial Instruction videos viewed them as a positive effect on their work.

Research question 4: *How should educational videos and other tools be developed and used in the Remedial Instruction to improve their effectiveness in the future?* In the view of this thesis, well made educational videos can serve as an important tool in teaching mathematics at TUT. Their effectiveness is especially in solidifying students' skills in basic knowledge, and in revising the basic routines that any student studying mathematics desperately needs. The FEV is now ready for use, but will need further iterations and more in-depth analysis in order to be an effective tool at any teacher's reach.

In the future, using the same platform for the Remedial Instruction and the videos associated with it would be useful. This would further eliminate any extraneous processing that using two different platforms might cause. Checking and updating the content in Math-Bridge should be done in order to be able to provide students with the best possible study content. Also, modernizing the BST and the Remedial Instruction as a whole could be studied. The most important questions that need answering are: is the passing point limit of the BST too low, and does the Remedial Instruction help the students of today as well as it did in the past? Due to the ever changing high school curricula, the Remedial Instruction must change as well, least it be left as an outdated part of remedial education, which would decrease its effectiveness. As the Basic Skills Test and Remedial Instruction are designed to measure if students have sufficient skills for TUT's mathematics, they can work together: the BST could point out the lack of skill in different areas, and the Remedial Instruction could be crafted to bring students to the starting level that TUT desires.

As can be seen from the results of the first course exams, failing the BST is already a sign that students will most likely have a lot of problems in the exam. However, the Remedial Instruction very likely has a positive influence in the grades, and removing it could have devastating effects on the passing rate of students that are struggling in mathematics. For this reason, it is quite clear that the Remedial Instruction is an important part of university mathematics, and that developing it is a fruitful use of time and resources.

It is common for these kinds of studies to discuss the concepts of reliability and validity regarding the work done in the study. The calculations in this thesis are based on the data generated by student activity during the beginning of the courses Engineering Mathematics 1 and Mathematics 1, as well as the exams of these courses. Data has also been collected from students using a questionaire. Even though the data is somewhat randomly generated, in the few following years similar studies are possible to be replicated, and similar results would probably be found. Also, the results found in this thesis would implicate that the Remedial Instruction and Basic Skills Test are useful tools in TUT's mathematics teaching. This is in line with previous research, and thus the results could be considered reliable.

When considering the concept of validity - i.e. does the study effectively provide information about the topic of research, and are the found results the correct ones - some observations should be discussed. The videos and the FEV were created using commonly approved pedagogical frameworks. A questionaire from the videos was created using triangulation, and the results of the questionaire were analyzed using statistical tools that are considered standard in the field. Also, the new additions (creation of educational videos and measurement of use of tools) brought up by this thesis provide additional value in mathematics teaching research. However, it should be noted that the students in the study were Finnish engineering students, and it is difficult to say if similar results could be found in other countries or even in other Finnish universities. However, similar learning profiles have been discovered in other schools as discussed in the SUAS case.

The results in this thesis state that mathematics videos can be an effective tool for some of the students in the Remedial Instruction. Development in the Remedial Instruction should be done by closely following the change in skill level of students starting their studies at TUT, and providing material that would bridge the gap between the first university course and the skill level after high school. The results also show that continued development of supporting mathematics tools is vital for the success of TUT's mission: training engineers that are able to answer to the problems of today's society. In this task, mathematics plays an extremely important role.

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A. QUESTIONAIRE ON REMEDIAL MATHEMATICS

This appendix contains the questionaire used in verifying the results found when looking into the data of the Basic Skills Test and the Remedial Instruction Program. The questionaire was posted as a Moodle2 -question form.

1. Student Number
2. Did you watch the Remedial Instruction videos (yes/no).
3. I felt that watching the videos helped me in solving the Remedial Instruction exercises. (Likert)
4. The subject matter was presented clearly in the videos. (Likert)
5. The sound and picture quality of the videos was good. (Likert)
6. The videos were easily available. (Likert)
7. The videos were suitably long in duration. (Likert)
8. I didn't watch the videos, because I did not know there were videos available. (Likert)
9. I didn't watch the videos, because I already knew how to solve the problems they addressed. (Likert)
10. I didn't watch the videos, because I dislike educational videos. (Likert)
11. I didn't watch the videos, because I used other tools to finish the problems. (Likert)
12. I didn't watch the videos, because of another reason (specify below). (open)
13. The Remedial Instruction lasted for four weeks. I solved most of the problems (In the first/second/third/fourth week / I solved problems throughout the four weeks)
14. The amount of hours I used on the instruction was approximately (0-5/5-10/10-15/15-20/20-25/25+)

15. Choose from the following all the tools you used in the Remedial Instruction:

    Pen & paper; Wolfram Alpha; CAS calculator; Function calculator; High school books; Remedial Instruction teaching material; Remedial Instruction model answers; Remedial Instruction educational videos.

16. The problems in the Remedial Instruction were of reasonable difficulty. (Likert)
17. I felt that the Remedial Instruction helped me to remember high school mathematics. (Likert)
18. I felt that the Remedial Instruction helped me in the first course of Engineering Mathematics.
19. I worked together with my fellow students to solve the problems.
20. If I needed help with the Remedial Instruction, it was easily available.

B. QUESTIONAIRE ANSWERS

1. Student numbers will not be presented here.

2. Yes 11, No 58

3. For students that watched the Remedial Instruction videos:

Question	Str. d.	Smw. d.	I don't know	Smw. a.	Str. a.
Q3	0	0	0	5	6
Q4	0	0	0	6	5
Q5	0	1	0	5	5
Q6	0	0	0	5	6
Q7	0	0	1	5	5

9. For students who didn't watch videos:

Question	Str. d.	Smw. d.	I don't know	Smw. a.	Str. a.
Q8	24	9	4	11	10
Q9	11	16	5	20	6
Q10	20	11	7	14	6
Q11	3	5	4	22	24

13. Open question

    - "I was not able to log into the system."
    - "I was in a hurry to complete the Instruction."
    - "I only noticed one video."
    - "I had successfully completed the Basic Skills Test."

14. First week 9, second week 13, third week 14, fourth week 13, throughout 20

15. 0-5 hours 14, 5-10 hours 25, 10-15 hours 15, 15-20 hours 6, 20-25 hours 6, 25+ hours 3

16. Use of tools

    Pen & paper 66

    Wolfram Alpha 33

    CAS calculator 15

Function calculator 38

Highschool books 21

Remedial Instruction Teaching Material 35

Remedial Instruction Model Answers 55

Remedial Instruction Educational Videos 11

17. User experience

Question	Str. d.	Smw. d.	I don't know	Smw. a.	Str. a.
Q16	1	9	3	22	24
Q17	1	1	4	22	41
Q18	6	10	6	24	23
Q19	51	5	1	10	2
Q20	2	4	23	21	19