The resource decisions and documents of undergraduate engineering students in mathematics courses

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Summary

This thesis concerns a multiple case study, carried out at three Norwegian universities. The goal was to find similarities and differences between how engineering students from different university contexts used resources to learn mathematics, and how they made decisions regarding their use of resources. My project had an inductive focus, networking thematic analysis (Braun & Clarke, 2006) with the theoretical framework of the documentational approach to didactics (Gueudet & Trouche, 2009). After my analysis, I also compared my results and conclusions to those of authors who have conducted research projects with a similar focus (i.e. Anastasikis, 2018; Gueudet & Pepin, 2016; Kanwal, 2018; Pepin & Kock, 2019). I generally found that my results were consistent with their reflections, but I had also identified trends that went beyond the ideas within the field.

Given the wide focus of the project, the result are numerous, and vary greatly in generality and theoretic value. There are two overarching results that I consider particularly significant to the field of research:

I identify an overall structure to students' decision regarding resources. Students almost exclusively consider resources that are emphasized within the course at hand; that they are familiar with from previous educational experiences or that they are familiar with from non-mathematical activities (for instance YouTube and Google). They primarily make their decisions based on what seems suitable for the task at hand, with preference as a secondary concern. Examinations have a significant impact on what they consider suitable. Their preference for resources are based on quality criteria such as simplicity and that they are able to use the resources efficiently.

I introduce the notion of didactical resource purposes. Students use resources for the four purposes of introduction, practice, evaluation and explanation. That is, they use resources to learn the theory and foundations of a topic; to gain experience working mathematically within the confines of the topic; to evaluate their answers, their learning process or their understanding of the topic and to actively search for information when they realize that there is a fact that they do not recall or an aspect of the topic that they do not understand well enough to accomplish their goals.

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Chapter 1: Introduction

In university mathematics, students are given more agency than in their previous educational experiences. Many organized sessions are not mandatory, and while the university provides students with resources they can use, deciding how to use them to learn is ultimately the students' responsibility. Students can use resources beyond the ones that the university provides, at which point a plethora of resources are available to them. The resources freely available online (open educational resources) are particularly plentiful (Trouche, Gueudet & Pepin, 2018). Students can make their own decisions about which resources to use, when to use them and what other resources to use them in combination with. They can develop systems of strategies tied to the use of several resources for various purposes. I contend that understanding students' resource use as a whole can give great insight into their engagement with university mathematics. In the long term, it can help lecturers, student councilors and other university personnel provide students with useful guidance on how to develop good study habits tied to resources. This project investigates various aspects of students' use of resources, aiming to build a strong foundation for further research.

1.1 The purpose of the thesis

I consider science to be a global, cooperative effort. Within each field of research, every scientist needs to consider the current state of the field, in order to determine how they can design their research to contribute to it. After conducting their research, they should once again consider the state of the field of research, how they have contributed to it and what further research the field may benefit from. Considering the state of the field involves looking at which ideas exist within the field of research and the strength of the evidence that supports those ideas. It also involves consideration of what the goals for research into a given field should be. With that in mind, this section will detail what I see as the goals behind studying university students' use of resources to learn mathematics and how I aim to contribute to the field.

Trouche and Fan (2018), wrote that holistic study of teachers' use of textbooks and other resources was a new field of research, that only recently gained sufficient attention to warrant a specific topic study group in a major mathematics education conference. Students' use of resources is an even smaller field. It should be noted that the field of research progressed considerably between the start of my project and the time at which I started the writing process. When I began the project, I understood there to be little or no research within the field. Given this understanding, I had to base my research foci and research design exclusively on what I thought the goals of the field of research should be and how I thought research ought to be conducted in a relatively new field.

In my opinion (which I do not think is controversial), the goal of mathematics education should be to maximize the successful learning of mathematics. I would say that the main goal for this particular field of research would be to maximize the extent to which mathematics educators can guide students towards successful strategies for using resources to learn mathematics. Using reverse engineering, I propose that there are several important subgoals that must be pursued in order to enable pursuit of the main goal. One is to develop knowledge on what resource strategies lead to successful learning. Another is to develop knowledge of the mechanics by which mathematics educators can guide students towards adopting certain resource strategies. In order to develop knowledge of successful resource strategies, one first needs to develop knowledge on what it means to successfully learn mathematics, possibly considering what role mathematics do, can and should play in society. One also needs to develop knowledge on the various types of resource strategies that could be used to learn mathematics. In order to understand the mechanics by which mathematics educators can guide students towards certain resource strategies, one should first understand how students make their decisions regarding use of resources. Figure 1.1 summarizes my above statements about the main goal of the field of research and what subgoals are pre-requisites for the main goal.

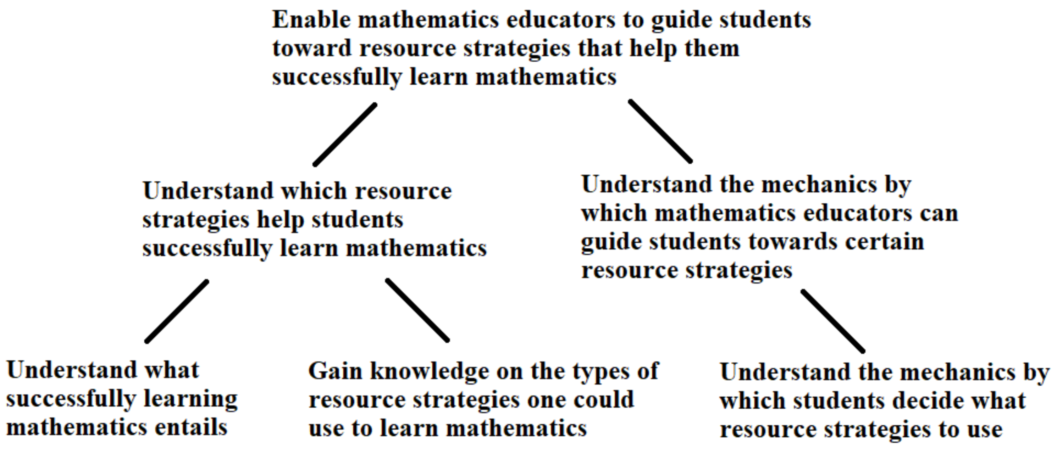


Figure 1.1: The main goals and some of the subgoals within the field of research tied to students' use of resources to learn mathematics. The main goal is for mathematics educators to promote students' successful learning. It requires knowledge of how educators can influence students, which in turn requires knowledge on how students make decisions. The main goal also requires knowledge on what resource strategies lead to successful learning, which in turn requires knowledge on which resource strategies there are and what successful learning of mathematics entails.

Of course, a large number of lower-level subgoals could be attached to the subgoals that I have already mentioned. For now, I consider these six goals to form a satisfactory model for the task of the field of research. At least, it helps me describe the purpose of the project at hand. It is intended to deal with issues related to which resource strategies exist and how students make decisions regarding resources.

Reflecting further on what the field of research might need, the field of research might benefit from investigating a broad range of issues to gain an overview of the field. This could help identify topics that require further, more in-depth research. I decided early that a large part of my project would be inductive, and that I wanted to ask open questions to see what issues the students found to be relevant to their use of resources. The idea was to be open to expanding the focus of the research based on what the participants discussed, and not make a final decision on research foci until the end of analysis. I also considered it important to study multiple students from multiple universities for the potential of getting multiple student perspectives on using resources in mathematics.

While an inductive approach seems fitting for a new field of research, most fields of research relate to other fields in some way. In research on education, one needs to consider the relationship between teaching and learning. The teacher must consider what learning they want to occur before they teach. While they can never predict with absolute precision what the students will learn, there can be some correlation between teaching and learning, and a causality is always intended. When investigating resources, I reasoned that considering a theoretical framework based on how teachers use resources to teach may provide useful terminology for discussing students' use of resources and help formulate some initial research foci to guide the research design.

The theoretical framework of my project is the documentational approach to didactics (Gueudet & Trouche, 2009), while the analysis strategy is thematic analysis (Braun & Clarke, 2006). In the case of the documentational approach, I reasoned that the field of research may benefit from a theoretical framework, and there may be potential to create a version of the approach that dealt with students' use of resources. After identifying issues related to students' learning, I will also discuss what implications they might have for such an approach.

I decided to adopt a mixed methods paradigm (Johnson & Onwuegbuzie, 2004), based on the tradition of pragmatism (James, 1907; Rorty, 1991). This decision stems from my personal perspective on mathematics education research and research in general. Researchers should consider what consequences their research could have and how their research may benefit society as a whole. I also thought that both quantitative and qualitative methods could be useful to my research, making mixed methods a suitable paradigm.

In summary, the main strategies and goals guiding my research are for it to be partially deductive, with a large inductive component; to focus on resource use as a whole with a student-centered perspective; to have a broad focus, trying to identify a great number of issues related to what resource strategies students use and how they decide on their resources and strategies; to focus on multiple students in different institutional contexts in order to identifying a variety of issues; to give an overview of the field of research and to consider whether a theoretical framework for students' resource use can be created using the basic structure of the documentational approach to didactics.

1.2 Overview of the thesis

In this section, I describe the role of each chapter after this introductory chapter.

At the end of chapter two, I present the research questions and project aims within my research. The rest of the chapter leads up to it by covering theories and existing research within the field. I will discuss how I carried out the multiple phases of my literature review. I will describe the theoretical framework of the documentational approach, as well as theories that are particularly relevant to many researchers within the field (or related fields with ideas relevant to the field). I will establish working definitions within my project and existing literature within the field. I summarize the field of research by identifying 37 ideas within the field that are particularly relevant to my focus.

In the third chapter, I discuss my research paradigm, research design and tools for data collection and analysis. Since the documentational approach has implications for how to conduct research, I discuss those as well. My research paradigm is mixed methods (Johnson & Onwuegbuzie, 2004), with reference to pragmatism (James, 1907; Rorty, 1991). My research design is a multiple case study (Yin, 2009). My data collection methods include interviews, schematic representation of resource systems (Gueudet & Trouche, 2011) and a questionnaire app named Studert. For the interviews with students, I use hierarchical focusing (Tomlinson, 1989). I use thematic analysis (Braun & Clarke, 2006) to analyze the data.

Chapter four contains the results. First, I describe the structure of each of the three courses in the study (at three different universities), while providing information on the grade distribution. Then I summarize the data collected on each of the nine students in the study individually, including their grade, their use of resources and any particularities of the data collection that may be relevant to the interpretation. Thirdly, I quantitatively analyze the schematic representations of resource systems (SRRSs) and lastly I identify themes based on the interviews, and discuss the degree to which data from the SRRSs and the app serve to support or contradict the themes. I organize the themes by sorting them into the theme categories classes of situations; schemes of utilization; evolution of documents; didactical resource purposes; resource decisions; resource discovery; quality criteria and other results.

In chapter five, I address the research questions based on the results. Among the result I discuss, I found that students developed documents for rather general classes of situations; that experienced difficulty was a factor that greatly influenced their resource use; that they often used emphasized resources first, while non-emphasized resources were used as a “plan B”; that students emulated the exam situation when they prepared for exams; that they primarily considered resources that they were familiar with when deciding on resources; that their resource decisions were primarily based on what resources they considered suitable, with personal preference as a secondary concern and that most of their quality criteria for resources were tied to efficiency.

In chapter six, I relate my ideas to existing ideas within the field and my contributions to the field. Among the new ideas I introduce is a theory of stages of using resources to learn that I coin “didactical resource purposes”. This results in a new summary of the field of research with 56 ideas. I then move on to consider what implications my research has for the potential of a student-centered version of the documentational approach and what questions are still left to be answered before one should use such a framework.

In chapter seven, I summarize my results, consider the limitations of my research and discuss the implications for future research within the field.

Included as appendixes are my strategies for conducting (appendix A, page 293), transcribing (appendix B, page 294) and translating (appendix D, page 299) the interviews, as well as constructing schematic representations of resource systems (appendix C, page 296) and referring to excerpts (appendix E, page 301). I include translated and original transcripts from interviews with course organizers (appendixes F-H, starting on page 303) and a list of all the excerpts I use from the students, sorted by student and chronology (appendix I, page 320). I also include a list of the resources mentioned (appendix J, page 401); all the schematic representation of resource systems with digital representations of the Norwegian mind maps that they are based on (appendix K, page 407) and a list of all the themes and results I identified (appendix L, page 424).

Chapter 2: Literature review and theory

At the end of this chapter, I will present my research questions and the aims of my research. The rest of the chapter is intended to establish the theories and ideas that are relevant to said questions and aims. I will discuss how I searched for literature; describe the theoretical framework of the documentational approach; discuss my initial views on the potential for a student-centered version of the documentational approach; discuss a few theoreties that I think are particularly important to the field of research; discuss my use of some terms that are particularly central to the project; discuss the ideas found within the field of research and finally present my research questions and aims.

2.1 Conducting the literature review

I conducted the literature review in four phases. I conducted the first phase of the literature review when the project was in the planning phase (January-April 2017), the second phase midway through collection of data (November 2017), the third phase after I had analyzed my data (January, 2019), and the fourth phase in June 2019 based on feedback after the 90 percent seminar of my project. The majority of the body of literature I use in this thesis I found through the structured literature review, while some articles recommended by my supervisors based on relevance to my project.

The first phase of the literature review focused on literature relating to theories and methodology, as they were central in the planning phase. At the time, I was participating in a mandatory methodology course. I conducted the methodology portion of the literature review by reading course literature and identifying methodologies for further consideration. Bryman's *Social research methods* (2015) was a particularly useful resource for identifying methodological issues and getting an overview of the body of methodologies to consider. I conducted the theoretical portion of the first phase of the literature review by searching Google Scholar for information on theoretical frameworks I considered using. For this portion, potential candidates were based on recommendations from supervisors. I was recommended to consider the documentational approach to didactics first, then potentially move on to check the semiotic approach. I decided on the documentational approach. During the first phase of the literature review, I attended CERME10 in the thematic working group for teaching mathematics with technology and other resources. Reading papers submitted to that group helped me get an overview of the field of research.

In the second phase of the literature review, I conducted a thorough search through leading journals in mathematics education. A mandatory course lead to the necessity of conducting this phase at that point. At the time, I had conducted my second interview with each participant and had a rough idea about which issues would be in focus in my analysis. I knew that the literature directly related to my focus was limited, so I also looked for literature with an indirect connection to my focus. At this stage, I was interested in finding:

A. Articles that used the instrumental or the documentational approach to didactics.
B. Articles related to student's resource use in general.
C. Articles related to the use of a specific resource.
D. Articles related to teacher's use of resources in general.
E. Articles related to secondary-tertiary transition.
F. Articles related to students' experiences with calculus.

For articles in categories A, C, D, E and F, I additionally consider whether differences between the authors' focus and my focus resulted in lack of relevance. For articles on the theoretical framework, I was looking for articles related to secondary or tertiary education. For the other categories I looked for articles that I would generally consider relevant to the statements of the participants in my research and to my discussion of the results. That is, their results section should either contain observations similar to my own observations during data collection, observations that seemed contrary to them or observations that might provide more insight into topics raised. I would also reject articles whose focus was too different from mine, for instance by focusing on children's learning or by focusing too much on the teachers' perspective rather than the students'. In short, for each article I considered the likelihood that I would use it in the thesis.

The third phase of my literature review involved expanding the second phase of the literature review by looking at issues that had come out between November 2017 and January 2019 and by looking into conference papers. Since I conducted the third phase after data analysis, I had a better idea of what would be relevant, for instance knowing that the influence of various issues related to secondary-tertiary transition and calculus courses were hardly represented in my data. This affected the degree to which articles and papers related to these issues were considered and eventually included. In the fourth phase, I added one conference, one journal and one additional article to my list based on recommendations.

The journals I searched through during the second through fourth phase of the literature review were Journal of research in mathematics education; Educational Studies in Mathematics; Mathematical Thinking and Learning; the International Journal of Research in Undergraduate Mathematics Education; the International Journal of Science and Mathematics Education; ZDM; Journal of Mathematical Behaviour; Research in Mathematics Education and NOMAD. For each journal, I browsed issues from 2010 to January 2019. I read the title of every article submitted and downloaded every article that looked like it might fulfill my criteria. In some cases, I read the abstract before making a decision. Although time-consuming, I considered this search process to be preferable to a database search due to the complexity of my criteria. I used the same criteria and process to find papers from the following groups within conferences:

A. The first two INDRUM conferences (all thematic working groups).
B. The seventh and eight ERME conferences (TWGs 14 and 15)
C. The ninth through eleventh ERME conferences (TWGs 14 through 16)
D. The twelfth ICME conference (TSGs 2, 13 and 19)
E. Book based on TSG 35 in ICME13 (Fan, Trouche, Qi, Rezat & Visnovska, 2018)

It should be noted that at the time, I had access to the CERME11 papers by virtue of being a participant. Not all papers were later published in their entirety.

I decided to conduct the most thorough parts of the literature review late due to the inductive nature of my research project. I considered it important to interpret the results with limited exposure to existing theories and would rather review literature on the field of research after my inductive analysis was concluded. However, description of a structured literature review was a requirement in a mandatory theory course I participated in during the second semester. Hence, institutional requirements dictated that the second phase of my literature review had to be conducted earlier than my preference. Due to my views on how to conduct an inductive analysis, I did not read all the articles from the second phase in great detail at the time, reading them more carefully at the time of the third phase of the review.

2.2 The documentational approach to didactics

The documentational approach to didactics was founded by Gueudet and Trouche (2009). It is heavily inspired by the instrumental approach, which is founded on ideas by Rabardel (2002). In order to understand the documentational approach, it is important to understand the instrumental approach, as well as terminology appropriated from other authors. However, it is also important to understand the major differences between the two approaches. The documentational approach looks at resource use as a whole rather than at individual resources; focuses on teachers' resource use rather than that of students; and more explicitly considers the goals of the activity and the institutional context that the activity takes place within. In the following subsections, I will discuss the roots of the documentational approach (primarily focusing on the instrumental approach); the structure of the documentational approach; present an example of a study using the documentational approach and discuss the potential of creating a student-centered version of the documentational approach.

2.2.1 The theoretical roots of the documentational approach

Within French didactics, there is a line of inspiration stretching from Piaget to the documentational approach. The work of Brousseau was inspired by Piaget. Brousseau inspired Vergnaud, who in turn inspired Rabardel. Rabardel's instrumental approach in turn inspired the founders of the documentational approach. As I go on to discuss the instrumental approach, I will refer to these authors when their contribution to the terminology of the approach is particularly significant.

The instrumental approach (Rabardel, 2002) concerns itself with the breadth of human activity that can be described in terms of interaction with *artefacts*, understood not only as physical tools, but also cognitive and social ones.

Rabardel argues that artefacts are not simply mediational means, but significantly shape actions, so one should talk about people's interaction with artefacts.

> Artifacts are not only individual means. They are bearers of the division and sharing of labor and their significance is incorporated in social practice. As a result, artifacts evolve constantly and reflect a historical state of users' practice at the same time as they model this practice. (Rabardel, 2002, p. 17)

The instrumental approach relates to a Vygotskian tradition of considering people and tools equally when people act using tools. As summed up by Wertsch (1998), it is important to emphasize the role of both the subject and the tool in an action. Wertsch, for instance argues that when solving 343 times 822 by paper, you ought to say that the problem was solved by the interaction between you and the standard algorithm for multiplication.

Rabardel introduces the term *instrument* to encompass both an artefact and the ways in which the subject interact with the artifact. He defines instruments as "the subject's use of the artifact as a means he/she associates with his/her action" (Rabardel, 2002, p. 18). He also says that an instrument can be understood as a "mixed entity made up of an artifact and a scheme" (Rabardel, 2002, p. 37), and later calls these schemes *utilization schemes*. In a simplistic manner, the idea of an instrument can be summed up as the equation "Instrument = artifact + utilization scheme" (Gueudet & Trouche, 2009, p. 205).

The term scheme is central to Piaget's teachings, and have been appropriated by the authors mentioned in the opening paragraph of this subsection, often providing their own definitions of the term. While Rabardel provides his own definition of a scheme (Rabardel, 2002), which is used in the instrumental approach, the founders of documentational approach refer to the definition of scheme by Vergnaud (i.e. Gueudet & Trouche, 2009; Gueudet & Trouche, 2011; Gueudet, 2016). Vergnaud's definition is: "Scheme: Invariant organization of behavior for a certain class of situations." (Vergnaud, 1998, p. 229)

Vergnaud goes on to describe four factors that the organization of behavior consists of. Firstly, goals, subgoals and expectations shape the organization of activity. Secondly, there are rules of action tied to situation, which generate behavior. Thirdly, the operational invariants, which consist of people categorizing and selecting information based on their understanding of the relevant concepts (concepts-in-action) and acting according to propositions they hold to be true (theorems-in-action). Lastly, the organization of activity is shaped by possibilities of inference.

From Vergnaud's definition of scheme, the notion of a situation and a class thereof is relevant. The term situation, as it is understood in French didactics, derives from the work of Brousseau and his theory of didactical situations. Brousseau (1997) agrees with a Piagetian view of learning and addresses the issue of what a teacher's role is given a view that students learn through assimilating or accommodating new knowledge resulting from new experiences. According to Brousseau "the teacher must imagine and present to the students situations within which they can live and within which the knowledge will appear as the optimal solution to the problems posed." (Brousseau, 1997, p. 22).

The teacher sets up an artificial situation to maximize the chance that the student will acquire the desired knowledge when encountering it. These are didactical situations, which are characterized by problems and systems of interaction set up by the teacher. The goal, however, is for the students to build knowledge that they can apply to adidactical situations. These are situations outside instruction, with authentic problems and other systems of interactions. Explaining Brousseau's notion of situation, Artigue and Houdement emphasize that situation expands on the notion of a problem by considering the classroom context in order to determine what is truly at stake from the perspective of the students (Artigue & Houdement, 2007). For instance, the classroom context contains a series of expectations, stakes and systems of interaction.

A class of situation in the instrumental approach can be understood as a collection of situations where the problems, expectations and systems of interaction are similar enough for a student to apply the same instrument to each situation within the class.

The instrumental approach is often used as a framework to examine learning through the use of technology (i.e. Trouche, 2004; Artigue, 2002). The framework is useful to such research projects because a learner's interaction with an artifact will develop over time through that interaction. New instruments are constantly created as a result of this change in interaction, and learning can be considered as the development of instruments. The term *instrumental genesis* is used to describe the process by which an instrument is created (Rabardel, 2002). It consists of two sub-processes happening simultaneously and having opposite orientations. The *instrumentalization* process is directed towards the artifact, as the subject attributes a function to the artifacts and their interaction with the artifact is shaped by their efforts to accomplish their goals through the interaction. The artifact is affected through “selection, regrouping, production and institution of functions, deviations and catachresis, attribution of propertied, transformation of the artifact (structure, functioning etc.)” (Rabardel, 2002, p. 103). The *instrumentation* process is focused towards the subject and the development of utilization schemes. The artefact affects the interaction between subject and artifact by virtue of its affordances and constraints. The utilization schemes are affected in terms of “their constitution, their functioning, their evolution by adaption, combination coordination, inclusion and reciprocal assimilation of new artifacts to already constituted schemes” (Rabardel, 2002, p. 103). Figure 2.1 shows an illustration of instrumental genesis as applied to mathematics education (Trouche, 2004).

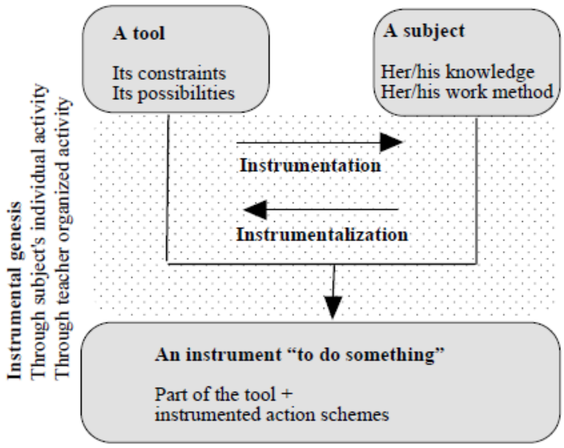


Figure 2.1: (Trouche, 2004, p. 289). Instrumental genesis is the process by which an instrument is created, consisting of the instrumentation process by which the tool affects the subject through its constraints and possibilities and the instrumentalization process by which the subject affects the tool through their knowledge and methods.

Rabardel has positive views on appropriation (Rabardel, 2002). It can be understood as making something one’s own (Wertsch, 1998). Rabardel has a positive view on people appropriating resources by finding their own ways to use them to achieve their goals, which may or may not correspond to the original intent of the designers of the resources.

2.2.2 The structure of the documentational approach to didactics

The instrumental approach can be useful in mathematics education when researchers examine how students interact with specific resources. However, the intentions of the documentational approach are more wide-reaching. Looking back at the early years of the approach, Trouche and Pepin (2014) expresses: “the objective of this approach has been to support a holistic view of all artefacts intervening in mathematics teaching.” (Trouche & Pepin, 2014, p. 157). Trouche (2004) introduced *instrumental orchestration* as an addition to instrumental approach that examined how teachers attempted to influence students’ instrumental genesis by guiding and facilitating their interaction with resources. Later Gueudet and Trouche (2009) founded the documentational approach to didactics (DAD) as a framework that used the ideas and structure of the instrumental approach and examined teachers’ practices and professional development.

In DAD, the main focus is that teachers use a set of resources in their professional practice and that they develop schemes of utilization related to the use of said resources. Teachers’ practice can be studied in terms of their resources and schemes, and their professional development can be understood in terms of changes over time to what resources and schemes they employ in their teaching. Because the documentational approach considers sets of resources, rather than individual artifacts, they introduce new terminology. Analogous to an instrument, a *document* is understood as the joint entity of a set of resources and schemes of utilizations (Gueudet & Trouche, 2009). Analogous to instrumental genesis, the development of documents is called *documentational genesis*, whereas the name for the processes of instrumentation and instrumentalization have been kept unchanged from the instrumental approach. However, focusing on a set of resources rather than an artefact, leads to the instrumentalization process encompassing more aspects than in the instrumental approach, such as revising the set of resources.

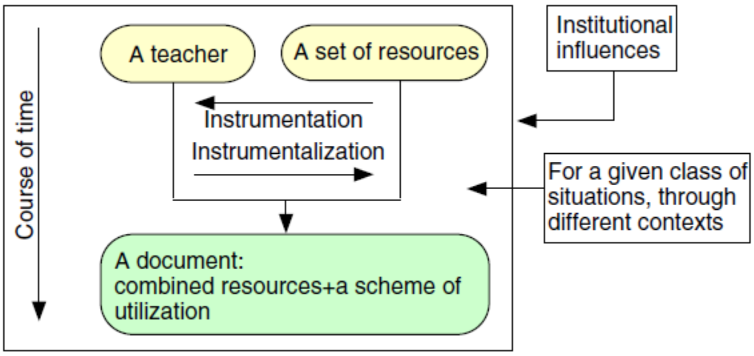


Figure 2.2: (Gueudet & Trouche, 2009, p. 206) Documentational approach is the process by which a document is created, consisting of the instrumentation process by which a set of resources influences the teacher and the instrumentalization process by which the teacher influences the set of resources. The document is created within and for a class of situation and the documentational genesis is also affected by institutional influences.

Figure 2.2 shows an illustration of the documentational approach from Gueudet and Trouche (2009), similar to the illustration of the instrumental approach by Trouche (2004) on page 13. A comparison between figures 2.1 and 2.2 reveals several changes. For instance, it is emphasized in figure 2.2 that documentational genesis is developed for a class of situation, through different context and that institutional influences affect documentational genesis. Gueudet and Trouche stresses the influence of activity theory (Vygotski, 1978; Leont'ev, 1979; Gueudet & Trouche, 2011), on the documentational approach's focus on teachers' activity being motivated and influenced by their goals. "Moreover, it must be studied as a social activity, which leads us to pay attention to its context: institution and different social groups." (Gueudet & Trouche, 2011, pp. 23-24) This makes it clear that a teacher's interaction with resources should not be seen as a purely individual endeavor, but as part of a social context, which influences their documentational genesis. It can influence what resources teachers use, which goals they use resources for, the rules of action guiding their use of resources, etc. The documentational approach's focus on goals guiding action, places it within a socio-cultural tradition (Wertch, 1998).

While the documentational approach talks about schemes of utilization, Gueudet and Trouche (2009) does not discuss these schemes in terms of the aspects mentioned by Vergnaud. Instead, they focus on schemes of utilization having visible and invisible aspects. The visible aspects are the observable similarities in the actions of the teacher within a class of situations, which in DAD are labelled *usages.* In the event that a teacher uses a resource once, it is simply a *utilization*. The invisible aspects are labelled operational invariants and are describes as the “cognitive structure guiding the action” (Gueudet & Trouche, 2009, p. 208). I interpret this as an attempt to combine all the four aspects mentioned by Vergnaud into one and to relate it explicitly to action. Gueudet and Trouche clarify that a researcher can try to infer operational invariants based on the *rules of action* they witness by observing several of a teacher’s usages, but that such an inference should merely be seen as a *possible interpretation*.

Documentational genesis as professional development is important to the documentational approach. Gueudet and Trouche (2009) argue that there is a dialectic between resources and documents. The development of utilization schemes for a set of resources may lead to including additional resources or excluding old ones. Thus, a new set of resources is formed, which in turn leads to the creation of a new document. This iterative process of development is illustrated with a helix, in which the upwards axis represents time (see figure 2.3).

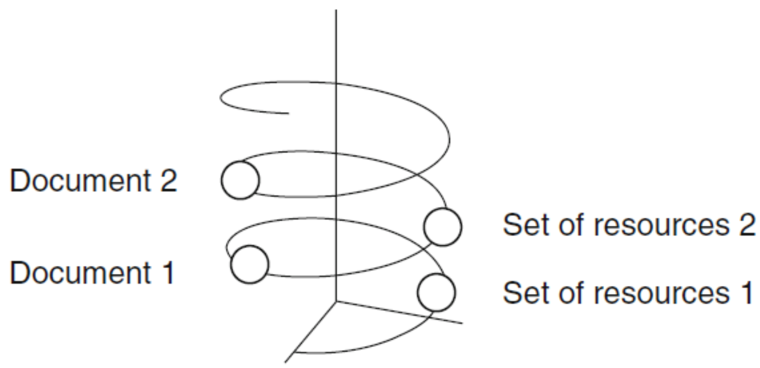


Figure 2.3: (Gueudet & Trouche, 2009, p. 206) There is a dialectic between the document and the set of resources, in that the creation of the document might lead to revision of the set of resources, which in turn leads to the development of a new document and so on. The upwards axis represents time, illustrating that documentational genesis should be seen as an ongoing process.

I think there is one key idea that is not mentioned in the documentational approach, but that follow from the ideas within it. Accepting that a document evolves through development of schemes related to a set of resources, I would argue that teachers (and more generally people) have invested much time into the resources that they already know and use. In the short term, it is more efficient to use a resource that you are experienced with than to start using a new resource. Even if the affordances of resource A are superior to resource B (when comparing their potential to help someone achieve their goals), people might choose to use resource B if they have developed schemes for it and consider the resource to be sufficient to achieve their goals. In the short term, it is more efficient to use an inferior resource with well-developed schemes than to use the superior resource with no prior schemes developed.

The documentational approach is not just equipped to examine a teacher's practice related to specific classes of situations (which is the purpose of individual documents). It is also intended to be able to study the teacher's practice as a whole, taking into accounts all of the teacher's documents and how the teacher uses them and works to develop them. Hence, DAD introduces several terms to study a teacher's practice and professional development more broadly:

- *Documentation system:* Encompasses all the teacher's documents, with a structural order that is shaped by the teacher's professional activity (Gueudet & Trouche, 2009).
- *Resource system:* Encompasses the resource part of a teacher's documentation system (Gueudet & Trouche, 2011). In other words, it encompasses any resource used in any of the teacher's documents. Gueudet and Trouche clarify that their use of the term is overlapping with, but not identical to how Kenneth Ruthven uses it as one of five key structuring features of classroom practice.
- *Documentation work:* The work that teachers put into developing their document system, particularly outside the classroom. Consists of "looking for resources, selecting/designing mathematical tasks, planning their succession and associated time management, etc." (Gueudet & Trouche, 2009, p. 201).
- *Documentation:* Encompasses both documentational work and the result thereof (Gueudet & Trouche, 2011)

Gueudet and Trouche make it clear that their conception of resources is broad, in that they study "sets of resources *not limited to curriculum material*, but including everything likely to intervene in teachers' documentation work" (Gueudet & Trouche, 2009, p. 200). They mention discussion with colleagues and students' worksheets as examples of resources that also needs to be considered. They also write that "For a teacher who draws on them in her activity, the reaction of a student, a wooden stick on the floor can also constitute resources". On multiple occasions (i.e. Gueudet & Trouche, 2009; Gueudet & Trouche, 2011; Gueudet, 2016), the founders of DAD refer to Adler (2000) as an inspiration for their conception of resources, and in particular the notion that one could consider "resource as the verb re-source, to source again or differently" (Adler, 200, p. 207). Adler argues that in addition to material and human resources, one should consider socio-cultural resources such as language. However, I have not seen anyone use DAD with a working definition of resources that is quite that wide in practice.

One central aspect of the conception of resources and documents within the documentational approach, is the idea that a set of resource or a document for a mathematics teacher has three components (Gueudet & Trouche, 2009):

- The material component, describing what kind of resources are involved, such as whether they are books, people or digital hardware or software.
- The mathematical component, describing the mathematical tasks, concepts and techniques within the utilization schemes.
- The didactical component, describing the organizational elements.

These components are exemplified in (Gueudet & Trouche, 2009), by looking at how a teacher taught a lesson on parallelograms. In table 2.1, I summarize their analysis of the components of the teacher's document.

Material component	**Mathematical component**	**Didactical component**
• Word processing software • Web sites • The digital textbook • Interactive whiteboard • Paper form to be filled out by students	Several properties and mathematical tasks related to the area of a parallelogram, such as the area formula.	"She will write the missing elements of the formula on the whiteboard, while the students do the same on the paper form" (Gueudet & Trouche, 2009, p. 208)

Table 2.1: Summary of a teacher's document used in (Gueudet & Trouche, 2009) to illustrate that a document consists of a material, a mathematical and a didactical component.

I think it is important to consider an example of using the documentational approach in order to understand the ideas within it.

2.2.3 An example of using the documentational approach

In this subsection, I will give a summary of how Gueudet describes the practice of the teacher Peter in a case study (Gueudet, 2014) and talk about how it illustrates the principles of the documentational approach, covered in the previous subsection. While it does not cover everything in DAD to a satisfactory degree, my hope is that it clarifies how the theory of DAD can be used to describe a teacher's practice.

At the start, Gueudet gives a background description concerning Peter and his institution, including that Peter has a PhD, obtain a full-time position as lecturer the same year he finished his PhD, that he teaches mathematics at a Universitary Technological Institute in France and information about such institutes in general and the specific institute in question. This illustrates that DAD sees the social context and institutional influences as significant to the teacher's practice, and as such, sees background information as vital. Gueudet goes on to describe the linear algebra course that Peter teaches, going over the length, the organized sessions and what resources are provided to the student. The weekly schedule involves a one-hour lecture, a two-hour paper and pencil tutorial and a two-hour session using Scilab at the computer laboratory. The resources for students include curriculum material at a Moodle platform. I would argue that this information can be linked to the didactical component of Peter's documents as it organizes activity.

Gueudet mentions a lot of resources that Peter uses, including books on the history of mathematics; the mathematics textbooks he used as a student; Scilab; LaTeX; Various software for combining web sites and wikis; Moodle; The websites of software he uses; personal web sites by colleagues; Wikipedia and material from courses he has previously produced. This can be considered Peter's resource system and relates to the material component of documents. Many of the resources are used to prepare sessions, showing that DAD emphasizes on professional practice both inside and outside the classroom.

Gueudet then talks about how Peter describes his students. For instance, many of them do not see mathematics as important in itself, but only as a tool for computer science. Their skills in and motivation for mathematics vary considerably. In addition to further establishing the social context, this leads into discussion of Peter's practice. In particular, his goals include raising the motivation of students. One of the ways in which he does that, is to use programming to make mathematics appear more practical and introducing students to "real applications" of mathematics in computer science. The assumption that these topics increase motivation can be considered the anticipation aspect of the operational invariants within Peter's schemes of utilization. Several rules of action are witnessed in his practice (or usages), for instance that he tends to use the visualization possibilities of Scilab.

When it comes to documentational genesis, Gueudet talks about Peter having adapted a lot of new digital resources throughout his career, and in order to learn how to use them (which can be considered development of utilization schemes), he tends to use the frequently asked questions sections of their associated websites.

In preparation for classes, Peter collaborates with colleagues to develop the text for Scilab tutorials. In keeping with the broad definition of resources within the documentational approach, this collaboration would also be considered a resource.

A peculiar fact, is that while Gueudet describes Peter as a technology enthusiast, he also uses a rather old textbook (from 1979) when preparing for class. The goal is to refresh his memory of the mathematical content. I think this illustrates the idea that developing schemes for using particular resources makes people invested in these resources, and that people are likely to continue using familiar resources as long as they help them achieve their goals to a satisfactory degree.

2.2.4 The potential of a student-centered version of the documentational approach

Looking at the instrumental approach (including instrumental orchestration) and the documentational approach, it is worth asking whether the two approaches complement each other and can be used to cover every aspect of the use of resources in mathematics education. On the surface, the instrumental approach appears to present a sufficient framework to examine students' use of resources, while the documentational approach covers teachers' use of resources and instrumental orchestration covers how teachers attempt to affect students' use of resources. However, a closer examination of the two approaches reveals that the differences between the instrumental approach and the documentational approach are larger than simply shifting the attention from students to teachers and updating the terminology. The term resource is broader than artefact and the documentational approach acknowledges that a variety of resources can be used in combination within the same class of situations and be used in the pursuit of the same goals. Trouche and Pepin (2014) argue the following:

> As compared to the instrumental approach, the documentational approach is not only a change of words, but we argue that it corresponds to a new viewpoint. When analyzing a teacher's work, also in university mathematics education, the documentational approach leads the investigator not only to look at a given set of artefacts, as did the instrumental approach, but to consider (as far as possible) the whole set of things feeding the teaching, as a coherent and articulated set of resources evolving for and from a teacher's activity
> (Trouche & Pepin, 2014, p. 157)

The documentational approach is quite focused on planning activity and professional development. I would argue that teachers' practice as described by DAD involves making more choices than students' activity the way it is described by the instrumental approach. However, it is my experience that in higher education, students are given more agency and responsibility and are presented with a variety of resources that they may choose to use. They are free to determine what resources are most suited for them personally. I see University mathematics as a context in which students can make choices about what resources to use and where they can use several resources in combination to achieve their goals. Hence, I think a student-centered version of the documentational approach would be preferable to the instrumental approach when studying how students at University use resources.

The possibility of adapting the documentational approach to look at students has also been considered by people central to the approach. Trouche and Pepin (2014) questions whether the instrumental approach is still appropriate, contending that the documentational approach is more holistic and deliver better on the original ideas that the instrumental approach was founded on. They go on to discuss its potential to be applied to students:

> The documentational approach is likely to provide rich analysis if used to evaluate students' or teacher-students' work in terms of interactions of different resource systems. […] the university mathematics education context offers ample opportunities for experimenting with the documentational approach. (Trouche & Pepin, 2014, p. 159)

In light of this potential within the documentational approach, I decided to use the documentational approach, in combination with inductive methods. I made it one of the aims of the project to identify implications for what ideas a student-centered version of the documentational approach ought to contain. I will refer to such an approach as a *documentational approach to learning* (DAL).

There are likely to be several differences between DAD and DAL, caused by differences between:

- Using resources to learn as compared to using resources to teach or to prepare a teaching session.
- The role of a student in the social context as compared to the role of a teacher.
- The goals of a student as compared to the goals of a teacher.

Before starting the project, I had an auxiliary hypothesis about how these differences would lead to theoretical differences between the frameworks: That the documents of students would be more general than the documents of teachers.

Put simply, a document is comprised of which resources a person uses, how they use them and why within a class of situations. The classes of situations that students experience may vary from the classes of situation that teachers experience, possibly requiring a reinterpretation of the theoretical term ‘situation’. Let us examine the idea of classes of situations and what situational factors may separate two classes from one another. Depending on the situational factors, classes of situations might be very general or very specific. General documents will include more situations than specific ones, but these situations will have less in common. For teachers, one could use the task as a situational factor and define very general documents, such as “preparing for class” and “teaching in class”. However, as illustrated in table 2.1 (page 19), topic may be used as a situational factor. This leads to more specific classes of situations, such as “teaching topics X to students at level Y”, where X is a collection of similar topics. The example used in the original article on DAD is “propose homework on the addition of positive and negative numbers” (Gueudet & Trouche, 2009, p. 205), which is a rather specific class of situations. Gueudet (2016) specifically says that while one could theoretically consider all the activity of a teacher to be one class of situation, she does not see such a level of generality as helpful, which I agree with.

For students, I would argue that it would be more useful to study their documents with general definitions of classes of situations. While a teacher may teach the exact same topic several times throughout their professional career, a student may only be expected to learn the same topic once. Hence, the iterative process of documentational genesis may be difficult to uncover from examining a students’ engagement with a single topic. Students’ may develop documents to apply to every situation in which they are expected to learn something new. These documents for general classes of situations may be more fruitful to examine through the lens of documentational genesis. Students need to develop documents with resources and schemes that will help them learn a variety of mathematical topics.

I contend that a working definition of class of situation is necessary for my project, because the situations that students encounter are more complex than classroom situations described by Brousseau. In his discussion of didactical contract, one of the perceived distributions of responsibility that Brousseau addresses is that “the teacher is supposed to create sufficient conditions for the appropriation of knowledge and must “recognize” this appropriation when it occurs." (Brousseau, 1997, p. 32). Implicitly, it may be inferred that a teacher should also recognize the lack of such an appropriation and take steps to facilitate the desired learning. This might be the case in a traditional classroom setting, but in large university courses, it is not feasible. Instead, the student themselves are responsible for recognizing their lack of learning and taking steps to overcome the issue. Hence, students will encounter situations in which the problems and stakes are defined by the university context, but there is no clearly defined system of interaction, and they themselves are responsible for organizing the activity. I will give my working definition in section 2.4 (page 25).

2.3 Pragmatic vs. epistemic value and procedural vs. conceptual knowledge

I will neither use the terms pragmatic and epistemic mediation, nor the terms procedural and conceptual knowledge in the analysis of my results. I will merely use the term understanding when it is used by students. However, these two theories are central to many researchers in the field, and will be important in chapter 6, when I discuss how my results relate to previous research.

While investigating the use of computer algebra systems (CAS) technology, Artigue (2002) used the terms *pragmatic* and *epistemic value*. The terms are originally founded in an anthropological approach, but are occasionally used by researchers using the documentational approach (i.e. Gueudet & Pepin, 2016; Kanwal, 2018). The *pragmatic value* of the method you use to solve a task is tied to its productive potential. When looking at mathematics students, an example could be that it helps you solve a problem quickly and correctly (Artigue, 2002). The *epistemic value* of a method lies in the extent to which it can help you gain understanding and organize your understanding of the concepts involved in the task. Using resources in a way that is likely to have higher pragmatic value can be called *pragmatic mediation* and using resources in a way that is likely to have higher epistemic value can be considered *epistemic mediation* (Gueudet & Pepin, 2016).

The ideas behind pragmatic and epistemic value and mediation relate to activity. Some ideas tied to cognition that also expresses a perspective with two different types of learning are *conceptual* and *procedural* understanding or knowledge (Hiebert & Lefevre, 1986). Conceptual knowledge involves knowledge of abstract concepts in mathematics and the relationship between them. Procedural knowledge involves knowledge of symbols, terms and procedures that are used to solve mathematical problems. *Meaningful learning* involves having both forms of knowledge and seeing the relationship between them. For instance, a student with good procedural understanding, but poor conceptual understanding or poor ability to connect the two, might be able to use the formula to solve a quadratic equation without understanding why said formula works or what the answer tells them about the curve of the corresponding quadratic function. Conceptual knowledge can make procedures easier to understand and remember while procedural knowledge can help make conceptual knowledge more meaningful, by tying abstract ideas to concrete symbols and problems. Focusing exclusively on procedural knowledge can lead to *learning by rote*, acquiring skills to solve a limited number of mathematical problem types, and maybe only when presented in specific forms.

I think there is a great, although not complete, overlap between what one theory would classify as epistemic mediation and what another would classify as symptoms of conceptual knowledge. Both theories are concerned that in many educational contexts, there is not enough focus on the concepts and relationships, and students would benefit from a more epistemic/conceptual focus. This is exemplified by some of the articles I will discuss from the field of research (i.e. Gueudet & Pepin, 2016; Kanwal, 2018; Randahl & Grevholm, 2010).

2.4 Working definitions in the project

There are some terms that are significant to the collection and analysis of data in my project and whose use I feel the need to clarify.

Resource: My working definition of resources is not as wide as the definition by Adler (2010) definition, but more in line with how I interpret the documentational approach. It does include social resources, but not language or reactions. In a sense, my definition is interactive, incorporating students' understanding of the concept. Participants were told that the project used a wide definition of resources. I specifically said that lectures could be considered a resource as it was something you chose to use in order to learn. Beyond that, I was curious what the students would consider resources given that description and did not do more to affect their personal definitions. If they asked whether something could be considered a resource during the interviews, I consistently answered yes. In analysis, however, if I considered something a resource and a student did not, I would treat it as a resource. For instance, I had predicted that not all students would intuitively consider social resources, so I asked about such resource specifically in case a student did not bring it up spontaneously. From my working definition, the following typology describes all resources mentioned by students.

- Social resources – people. For instance, fellow students or the lecturer.
- Social resources – events. For instance, lectures or support centers.
- Material resources – Self-made. For instance, lecture notes or reading notes.
- Material resources – Produced. For instance, textbook or pencils.
- Digital resources – hardware. For instance, calculator or laptop.
- Digital resources – websites/software. For instance, YouTube or GeoGebra.
- Digital communication resources. For instance, e-mail.

I would also consider social media to be part of digital communication resources, but no student in my study mentioned social media.

Emphasized resources: Within the context of a particular mathematics course, I consider a resource to be emphasized if a lecturer or course organizer signals to students that they recommend using it. Such signaling could include information on course pages or communication in lectures. Included in emphasized resources are resources provided by the university, resources that are mandatory to use, resources that are allowed at exams and resources that are merely recommended (verbally or at information pages). If the lecturer says during a lecture that it is their view that students learn more if they take notes during the lectures, then lecture notes would be considered an emphasized resource within that course. Also, if a lecturer recommended forming study groups, then fellow students would be considered an emphasized resource. Hence, the term ‘emphasized resource’ encompass more than the more commonly used ‘curriculum resources’ (i.e. Kock & Pepin, 2018). I will on occasion refer to a resource as heavily emphasized, when it is particularly clear that the organizers expect the students to use the resource a lot.

Search resources and utilization resources: A search resource is a resource used to find other resources. For instance, certain web pages can be considered resources to learn mathematics, and students often use the Google search engine to find such web pages, making Google a search resource. In the case of YouTube, individual channels or videos can be considered regular resources while the platform itself is a search resource. Students could use search resources to find resources to incorporate into their documents, or they could use them to find resources just for the problem at hand, that may potentially only be utilized once. When the latter is the case, I say that they are searching for utilization resources. See also, the difference between a utilization and a usage within the documentational approach (page 15).

Strategies: As I make an effort not to impose theoretical terms from the documentational approach onto the students, I use the Norwegian term for strategies in the interviews rather than the term schemes. I think students intuitively interpret this word as ‘what, when, how and why’, similar to how I interpret the idea of a scheme in the documentational approach. Throughout the text, I will use the term ‘strategies’ in sentences that focus more on the students’ experiences and statements and the term ‘schemes’ in sentences that focus on the theoretical framework of the documentational approach.

Class of situations: A collection of situations that have certain situational factors in common. A situation is defined as the joint entity of a problem or set of problems and the expectations, stakes and systems of interaction defined by the social context. Situational factors may include the nature of the problems, the types of goals students develop relate to the problem, and anything that may influence how the student interacts with resources to achieve their goals. The last point is quite open, and can include factors external to the students, such as the resources available, or internal factors such as how difficult the student perceives the problem to be, given their existing knowledge.

Prime document: Students may talk about their use of resources in a way that suggests that they have a set of resources and schemes of utilization that describes what they normally do. If so, when discussing situations that affect their use of resources, they discuss factors that make their resource use “different from what they normally do”. If so, I will say that the resources and schemes of utilization that students normally employ constitutes their prime document.

Learning: Within mathematics education, I define learning as any change that enables a student to solve mathematical problems (whether abstract or concrete) more consistently, more efficiently or with greater flexibility. Flexibility can include the ability to solve problems with multiple methods and the ability to solve types of problems that one has not been able to solve before.

Mind map / SRRS: To get schematic representations of the students' resource systems, I ask them to construct mind maps, which is a term familiar to Norwegian students as it is one of the learning strategies they are taught in school. In this thesis, I will use the term mind maps to mean the students' constructions, while I will use the term SRRS to mean the colour-coded figures that I construct based on their mind maps. For more information, see appendix C, page 296.

To make a resource your own: During the interviews, I had questions about appropriation, which I phrased by asking if there were any resources they felt like they had made their own. Most students asked for a clarification. When they asked, I told them that it included finding ways to use a resources that they had not been taught by anyone.

Idea: When discussing the field og research, I use the term idea. I do so because the term is emphasized by James (1907). My working definition of the term is that it can encompass both proposed facts, proposed causal links and theoretical viewpoints. My use of the term is also meant to emphasize that the degree to which the ideas are true can be discussed and investigated further.

Evidence: When I say that my project provides evidence to support an idea, I use it similar to the legal sense. That is, evidence is anything that provides increased reason to believe that an idea might be true (see section 3.1, page 45 for my definition of truth). It is notably difference from proof, which is a line of argument connecting several pieces of evidence in order to conclude that an idea is true.

2.5 Field of research

The third phase of the literature review revealed a significant increase in literature on students' use of resources as a whole within a few years. In addition, some literature with a different focus appeared quite relevant to the field of research. For instance, research on a certain resource could relate to more general issues. Ideas about calculus and secondary-tertiary transition could also shed light on the socio-cultural context that the students within my study find themselves in. In this section I will discuss research within the field and arrive at a summary of the ideas that are particularly relevant to my own research.

2.5.1 Research on students' use of resources as a whole

During the first phase of my literature review, I found no indication that anyone else had studied students' resource use as a whole. Gueudet, Buteau, Mesa and Misfeldt (2014), made an overview of studies that had been made using the instrumental and the documentational approaches. The article revealed no researchers using either approach to study students' use of resources in general. My supervisors and I were also unaware of any such studies using different theoretical frameworks. The second phase of my literature review did not reveal any such research projects either. However, the third phase of my literature review revealed papers from projects running parallel to my own. I was also made aware of an article in a journal that was not included in the second phase of my literature review (Teaching Mathematics and Its Applications), as well as the doctoral thesis by the first author of said article.

In the quantitative part of their study, Anastasikis, Robinson and Lerman (2017) asked second year engineering students for what resources they used and what resource was their first through fifth choice related to various purposes. They found that:

- Students mostly used provided resources as well as their own notes
- There was little variety in the students' first choices, and an increasing variety of resources mentioned as lower priorities. Five resources combined made up over 90 percent of the students' first choices, while the same number for their second, third, fourth and fifth choice were eight, ten, eleven and twelve resources, respectively.

- The students used some external resources like Wolfram Alpha and online videos, but they were used by few students and ranked low on their lists.
- The authors argue that human resources (including other students and the lecturer) were also mentioned at low ranks with low percentages. However, in the case of other students, I disagree that percentages were low. Their data shows other students to be the most mentioned fourth and fifth choices and the fourth most mentioned resource overall, behind the textbook, the course website and the students' own notes. The data also showed it to be the fourth most liked resource.

In the same project, they had a qualitative component concerned with the goals behind students' use of resources. They concluded that all the most common goals related to exams and implicitly to the goal of getting a good grade in the course.

Anastasikis' doctoral thesis (2018) concerns both engineering and mathematics students. The results include those of the journal article, except in the discussion, the doctoral thesis placed a higher value on the role of other students. Anastasikis quantitatively analyzed what resources were used in combination in order to identify a typology of tools that include peers (including communication tools), teachers (and support staff), external online tools, the official textbook (and other textbooks) and students' notes (from the course or from previous education). He also profiled students, identifying five large groups:

1. Peer-learning group: Students who used peer tools more than average and all other types of tools less than average.
2. Online-learning group: Students who used external online tools (slightly) more than average and all other types of tools less than average.
3. Blended-learning group: Students who used all types of tools more than average.
4. Predominantly textbooks-learning group: Students who used official textbook tools more than average and used all other types of tools considerably less than average.

5. Selective-learning group: Students who used teachers, official textbook and online videos more than average, and used peers, notes and the rest of the external online tools less than average.

Anastasikis found that mathematics students were more likely than engineering students to fit into the first three group and that second year engineering students were more likely to fit into the second and third group than first year engineering students. He also found some relationships between student profile and type of goals, in that students whose goals related to passing the course were more likely to use peers; students whose goals related to acquiring mathematical skills were more likely to be in the blended-learning group; students that had goals related to "opening your mind" were more likely to be in the selective-learning group and students with goals related to understanding the theory of mathematics were more likely to predominantly use the textbook.

In the qualitative portion of Anastasikis' project, he concluded that students' goals were primarily tied to assessment, either directly or indirectly (for instance, through practice). Several goals also related to understanding. Anastasikis posed that the students' focus on assessment need to be interpreted in relation to the larger sociocultural environment.

Howard, Meehan and Parnell (2019) also come to the conclusion that assessment is an important part of students' goals, as they investigate the resource use of business students within a mathematics course with continuous assessment. They found that the timing of the resources used is dictated by the weekly continuous assessment and weekly quizzes, with videos being watched prior to continuous assessment and worksheets and Maths Support Centre being used prior to quizzes. The students in their study could also use lectures and videos of those lectures. The authors conclude that some focused on one or the other, some focused on both and some switched which one they focused on through the course of the semester.

While Stadler, Bengmark, Thunberg and Winberg (2013) are mostly concerned with transition, their paper concerns resources quite a lot. They found that between the start and end of their first year at university, mathematics students start using the teacher less and internet-based resources and fellow students more. They also start seeing previous tests, peers, computer calculation and internet-based resources as more important, while formula books and calculator are seen as less important. In addition, they start seeing most study activities as less important, while working with peers is seen as more important. The authors argue that the students' initial views are based on secondary school experiences and change as they are faced with a new context.

Gueudet and Pepin (2016) have a joint focus on transition and resources as they examine two case studies. Similar to Stadler and colleagues, they found that there was a shift in resource use from secondary to tertiary education. The textbook appeared to have been the main resource at secondary school, while at university the lectures occupied that role. While at secondary, students used resources the way the teacher told them to, at university they were given plenty of resources to choose from. They found that during the first year, students' mediation with resources was mainly pragmatic and focused on worked examples and reproductive techniques. The authors argue that students align themselves to the more epistemic focus of the university considerably slower than the university staff assume they will.

Kanwal (2018) studies a Calculus course for undergraduate engineers in Norway and arrives at the conclusion that their mediation with resources is mostly pragmatic, but there was some epistemic mediation as students reported on using tutorial videos in order to understand the content. She also found that while students mostly used the main resources in the course (MyMathLabs, textbook, tutorial videos and to a lesser extent Maxima), they occasionally used the internet, online calculators, Wolfram Alpha or YouTube. Kanwal argues for more open-ended tasks within a course in order to lead students to a more epistemic mediation with resources.

In a research project focusing on first year engineering students in a Calculus (CS) course and a Linear Algebra (LA) course, Kock and Pepin (2018) arrive at several conclusions:

- Compared to secondary school, the students rely more on videos and social resources.
- Most (but not all) CS and LA students use the lectures as a "starting point".

- Online tests and weekly homework are used by the students to assess whether they had a “good understanding” of the content.
- The CS textbook (which was not specifically written for the course) is mostly used for exercises, with the teacher’s lecture notes being more important for learning the mathematical content.
- For LA students, a course-specific reader (similar to a textbook) written by their lecturer is “the backbone” of the course.
- Online videos and video-recorded lectures provide additional explanation to CS students.
- Several CS and LA students se friendship groups as important. They also ask questions of lecturers, but to a lesser extent.
- Students consider university mathematics to be more difficult and faster paced than mathematics at secondary.
- Students in the CS course find it harder to choose how to use the resources provided to them as there was little guidance from the university.

The authors conclude that students consider their secondary school experiences as a default position on resource use when they start at university, and then need to update it in response to increased difficulty. They also conclude that students prefer resources designed specifically to be aligned with the learning goals in a course, as was the case in the LA course. They need guidance for how to use resources when a lot of resources are made available, such as in the CS course.

Going deeper on the last issue, Pepin and Kock (2019), coin the term actual student study path to investigate which resources students use in what order for a mathematical topic. They note that in the LA course in their project, the study paths were similar to the lecturer’s intents, since the lecturer gave a lot of guidance, while for the CS course, the study paths were more varied. They give examples from various students. For instance, one student’s path is described as “lecture → tests → tutor hour & old exams → YouTube/Khan academy → homework (“reading text” & “do it”)” (Pepin & Kock, 2019, p. 6). They also conclude that students are focused on test and examinations; lecture; friends and social media and understanding.

Puga and Aguilar (2014) investigate what resources are used for “help-seeking” by undergraduate engineering students at a Mexican university. Help-seeking can be interpreted as anything that helps them overcome a specific difficulty they encounter in their study of mathematics. Puga and Aguilar found YouTube, Facebook and Google to be the resources that the students use the most for help-seeking. The quality criteria students based their decisions on included the amount of information available, how easy it was to find what one was looking for and the credentials of the people who created a resource (for instance in the case of YouTube videos).

While investigating differences and similarities between teachers’ and students’ assumption about norms that guide mathematics education, Gueudet and Pepin (2018) make several findings relevant to my research. The students in a case study in the UK did not see the textbook as very useful. They only asked the lecturer for help if unable to find the help they needed elsewhere. Similar to studies mentioned previously, the authors also find that students have to adapt to tertiary level being different from secondary, that students rely more on social resources and that students are focused on exam goals.

Robinson, Loch and Croft (2015) study the use of screencasts (which in my study would be classified as a form of video lecture), and also consider more generally resources for feedback. Similar to Gueudet and Pepin (2018) they find teachers to be the least used feedback resource. The video lectures are used a lot and the students appreciate the high level of detail and their ability to rewatch it and control the pace of information. They particularly appreciate getting detailed solution for a variety of exercises.

Raguel and Ogena (2012) approach resource use with a focus on coping-mechanisms when the students find the content to be difficult. They find that students try to work on exercises regularly, that they take notes and potentially mark important sections, that they ask fellow students for help and that many have an additional mathematics book to supplement the textbook.

2.5.2 Relevant research on calculus, transition and resource use from teacher-centered or non-holistic perspectives

This subsection mainly concerns articles from the second phase of my literature review. At the time I had conducted two thirds of the interviews and had a good idea about which issues regarding the use of particular resources, calculus and transition were the most relevant to the statements of the students who participated in my interviews. Hence, I was quite selective about which articles to include. A few are from the third phase of my literature review, after I had completed the analysis and had an even better idea of which issues were relevant.

According to Furinghetti, Maggiani and Morselli (2013), for transition from secondary to tertiary level mathematics to be successful, students need to realize that the content is an extension of the content at secondary school, whereas the approach to mathematics is different. In particular, the mathematics at tertiary education is more conceptual, whereas at secondary education is it more procedural. Breen, O'Shea and Peipffer (2013) conclude based on their literature review that there is broad agreement that university mathematics is, and ought to be, more conceptual. From their own results, they find that students generally appreciate more conceptual tasks, while most of them also saw value in largely procedural tasks.

On the topic of conceptual versus procedural understanding, Randahl and Grevholm (2010) analyze a textbook for first year engineering student and find that it focuses too much on procedural knowledge, making it challenging for students to gain conceptual understanding of the concept of the derivative. Other studies (Hoffkamp, 2011; Swidan & Yerushalmy, 2014) focus on how tasks can be designed with the visual aspect of functions in mind in order to facilitate a conceptual understanding of integration. The latter uses a dynamic geometry environment (DGE) in order to facilitate conceptual understanding. Leung, Baccaglini-Frank & Mariotti (2013) conclude that there is great epistemic potential in tasks designed for interaction with DGE. In particular, they find that clicking and dragging geometrical points that define a geometrical object can help students gain a deeper understanding of the invariant features of said geometrical object.

In addition to the aforementioned research on digital geometry environments, I have included two more studies on particular resources that relate to results in my data. These are not the main issues discussed in either study, but are smaller issues within them that are relevant to my data. Borba, de Souza Chiari and de Almeida (2018) notices that although pre-recorded videos are made available to students in a virtual environment, students also search for and add other videos that they find helpful. When studying the effects of a flipped classroom approach, Fredriksen, Hadjerrouit, Monaghan and Rensaa (2017) find that not all students appreciate the increased group work in class that this approach leads to. Some said they preferred working on their own. One reason given was that differences in mathematical skills between the individuals in a group and differences between the degree to which they had understood the videos they watched to prepare, made the discussion within the group less productive.

2.5.3 Summary of the field of research

Based on the literature I have covered in the previous two subsections, I would like to sum it up as 37 ideas from the field of research that are relevant to my project (see table 2.2). As I will discuss later, one of the features of the inductive approach to analysis that I use is that I did not want to read up on the field of research extensively prior to analysis. I did not want other people's research results to colour my interpretation of the data. Instead I wanted to compare my results to existing research once I had already conducted analysis. The ideas that I here use to summarize the field of research, I will compare to my own results in chapter 6.

Idea name	**Idea**	**Literature**
Idea 1	Students mostly use resources that are provided or otherwise emphasized in the course at hand, but to some extent they use external resources as well.	(Anastasikis et al., 2017; Anastasikis, 2018; Kanwal, 2018)
Idea 2	The internet, online calculators, Wolfram Alpha and YouTube are among the resources that student use even if they are not emphasized in the course at hand.	(Kanwal, 2018)
Idea 3	Students use the textbook and other resources more if they are tied specifically to the course at hand.	(Kock & Pepin, 2018)

Idea 4	There is little variety to what resources students use the most, but greater variety in their lower ranked resources.	(Anastasikis et al., 2017; Anastasikis, 2018)
Idea 5	Fellow students are used quite a lot, but at lower ranks.	(Anastasikis, 2018)
Idea 6	Students have different preferences between attending lectures and watching recorded lectures, and some switch which one they focus on in the middle of a course.	(Howard et al., 2019)
Idea 7	Students' resources mostly fit within the five categories of peers; teachers; external online tools; the official textbook and students' notes.	(Anastasikis, 2018)
Idea 8	Students mostly fit within the five profiles of the peer-learning; the online-learning group; the blended-learning group; the predominantly textbook-learning group and the selective-learning group.	(Anastasikis, 2018)
Idea 9	Students' goals regarding their use of resources in mathematics are mostly tied to assessment. Understanding is also a significant goal.	(Anastasikis et al., 2017; Anastasikis, 2018; Howard et al., 2019; Kock & Pepin, 2018; Gueudet & Pepin, 2018)
Idea 10	The type of goals a student has influences which learning profile they correspond to.	(Anastasikis, 2018)
Idea 11	Students' use of resources at the start of University is greatly influenced by their secondary school experiences, but changes as they encounter the university context.	(Stadler et al., 2013; Gueudet & Pepin, 2016; Kock & Pepin, 2018; Gueudet & Pepin, 2018)

Idea 12	Students rely more on video resources and social resources at university than at secondary school.	(Kock & Pepin, 2018; Gueudet & Pepin, 2018)
Idea 13	Students tend to have less guidance tied to the use of resources at University compared to secondary school and find it harder to make choices.	(Gueudet & Pepin, 2016; Kock & Pepin, 2018)
Idea 14	The less guidance the lecturer gives, the more varied students' use of resources is.	(Kock & Pepin, 2018)
Idea 15	Over the course of the first year, students: a) Start using the teacher less. b) Start using internet-based resources more. c) Start using social resources more.	(Stadler et al., 2013)
Idea 16	Over the course of the first year, students start seeing: a) Previous tests as more important. b) Peers as more important. c) Computer calculation as more important. d) Internet-based resources as more important. e) Formula books as less important. f) Calculators as less important.	(Stadler et al., 2013)
Idea 17	Besides working with peers, over the course of the first year, students start seeing every type of study activity as less important.	(Stadler et al., 2013)
Idea 18	Some students are more individually minded than other students. Individually minded students tend to see less benefit in working with students that are at a different level of mathematical skill than themselves.	(Fredriksen et al., 2017)
Idea 19	Study paths (which resources were used in which order) may be a fruitful way to investigate students' use of resources.	(Pepin & Kock, 2019)

Idea 20	Students often use the lecture as a "starting point".	(Kock & Pepin, 2018)
Idea 21	Tests and exercises are used to assess one's own understanding.	(Kock & Pepin, 2018)
Idea 22	Students tend to use video resources to get an additional explanation.	(Kock & Pepin, 2018)
Idea 23	Students tend to use YouTube, Facebook and Google for "help-seeking".	(Puga & Aguilar, 2014)
Idea 24	When video resources are provided to students, they will also look for additional video resources on their own.	(Borba et al., 2018)
Idea 25	First year students tend to focus on the pragmatic rather than the epistemic value of resource-mediation.	(Gueudet & Pepin, 2016; Kanwal, 2018)
Idea 26	Students appreciate both conceptual and procedural tasks.	(Breen et al., 2013)
Idea 27	Compared to secondary school, university mathematics: a) Is more difficult. b) Has a more conceptual focus.	(Kock & Pepin, 2018; Furinghetti et al., 2013; Breen et al., 2013)
Idea 28	Engineering textbooks at the start of University mostly focuses on procedural knowledge.	(Randahl & Grevholm, 2010)
Idea 29	Visual tasks can help facilitate conceptual understanding of integrals.	(Hoffkamp, 2011; Swidan & Yerushalmy, 2014)
Idea 30	Experimental tasks in dynamic geometry environments can help facilitate conceptual understanding of geometric objects and epistemic mediation.	(Leung et al., 2013)
Idea 31	Students do not appreciate the textbook very much at University level.	(Gueudet & Pepin, 2018)
Idea 32	Students ask the lecturer for help as a last resort, asking fellow students prior to the lecturer.	(Gueudet & Pepin, 2018; Robinson et al., 2015)

Idea 33	Student appreciate detailed solutions to exercises	(Robinson et al., 2015)
Idea 34	Students appreciate resources that provide highly detailed information and resources where they can control the pace.	(Robinson et al., 2015)
Idea 35	Students get a lot of help from fellow student when experiencing difficulty	(Kock & Pepin, 2018; Gueudet & Pepin, 2018; Ragual & Ogena, 2012)
Idea 36	Students consider it important to work on exercises regularly	(Ragual & Ogena, 2012)
Idea 37	Students often use other mathematics books in addition to the textbook	(Ragual & Ogena, 2012)

Table 2.2: A list of ideas within the field of research that I consider relevant to my work, with reference to articles that relate to them.

It is important to note that I do not think these results should be taken as facts. A result from a single study presumably holds true within the specific cultural and institutional context it was studied within. However, without a breadth of research on the same topic, within several different contexts, it is hard to say whether the experiences can be generalized. The ideas within table 2.2 that are supported by multiple studies are more likely to hold true in a variety of contexts. On the other hand, there are ideas that are somewhat contradictory, such as major ideas 9 and 10 about the degree to which students focus on conceptual understanding and the epistemic value of resource-mediation as compared to procedural understanding and the pragmatic value of resource-mediation. This might indicate that the results vary based on what context is studied. One of the reasons I chose to use the word ‘ideas’ is that I think it communicates that while there is some evidence to support these notions, there is also a level of uncertainty and a great potential for different interpretations. One of the main reasons I want to engage with these ideas, is that whether or not my results seem to support or contradict them helps further the field of research by giving us a little more data to use to discuss the potential generality and usefulness of the ideas.

In the interest of keeping track of the various contexts that the research behind those ideas took place in, table 2.3 shows the national context, educational context and research context of the studies mentioned above. In the case of tertiary level, I will include within the term educational context the question of what sort of program (mathematics, engineering etc.) the students within the study are engaged in. Research context includes research design and in particular whether the study is quantitative or qualitative.

Literature	**National context**	**Educational context**	**Research context**
(Anastasikis et al., 2017; Anastasikis, 2018)	Greece	Mathematics / engineering	Mixed methods
(Kanwal, 2018)	Norway	Engineering	Qualitative
(Kock & Pepin, 2018; Pepin & Kock, 2019)	Netherlands	Engineering	Qualitative
(Howard et al., 2019)	Ireland	Business	Mixed methods
(Gueudet & Pepin, 2016; 2018)	United Kingdom / France	Mathematics	Mixed methods
(Stadler et al., 2013)	Sweden	Various (not differentiated)	Quantitative
(Robinson et al., 2015)	United Kingdom	Mathematics	Mixed methods
(Ragual & Ogena, 2012)	Philippines	Mathematics	Qualitative
(Fredriksen et al., 2017)	Norway	Engineering	Qualitative
(Puga & Aguilar, 2014)	Mexico	Engineering	Qualitative
(Borba et al., 2018)	Brazil	Mathematics teacher education	Qualitative

(Breen et al., 2013)	Ireland	Primary teacher education / Humanities	Qualitative
(Furinghetti et al., 2013)	Italy	Mathematics	Qualitative
(Randahl & Grevholm, 2010)	Norway	Engineering	Qualitative
(Hoffkamp, 2011)	Germany	Secondary	Qualitative
(Swidan & Yerushalmy, 2014)	Israel	Secondary	Mixed methods
(Leung et al., 2013)	Italy	Secondary	Qualitative

Table 2.3: The national, educational and research context of the literature on which the ideas within this section are based.

2.6 Research questions and project aims

My research questions are partially based on the theoretical framework of the documentational approach and what I would intuitively consider important questions related to students' use of resources. It is partially based on my data, since my project has a large inductive component, leaving room for the participants to focus on the aspects that are important to them, which are then incorporated into the focus of the project.

RQ1. What resources do undergraduate engineering students use in mathematics courses and to what extent?
RQ2. What characterizes the schemes that students develop?
RQ3. What classes of situations do students develop documents for?
RQ4. How do students' documents develop over time?
RQ5. How do students decide on what resources to use?
RQ6. Which factors influence the students use of resources?

In order to fully answer the sixth research question; to provide context to discuss the answers to all the questions and to enhance discussion of generalizability, I will also answer what I will call contextual questions. I choose to make this distinction between research questions and contextual question in order to highlight that the former focuses on students' actual resource use and reflections regarding resource use, while the latter serves to put the results in perspective.

CQ1. What resources are emphasized in the courses at universities Alpha, Beta and Charlie?

CQ2. What other factors characterize the courses at the three universities?

CQ3. Do any of the participating students have previous experience with university mathematics?

CQ4. How well did the participating students do in the course that was studied?

The aims of my project are as follows:

PA1. Answer the resource questions based on a multiple case study that is partially inductive and partially deductive.

PA2. Compare the results of the multiple case study to existing ideas within the field of research, and identify relevant topics for further research.

PA3. Make an overview of what terminology and ideas a documentational approach to learning should include, and identify issues that need to be resolved.

After presenting my findings in chapter 4, the fifth chapter relates to the first project aim, while the sixth chapter has one section for each of the remaining project aims.

Chapter 3: Methodology and methods

My project uses a mixed method paradigm (Johnson & Onwuegbuzie, 2004) in accordance with an interpretation of truth based on the philosophy of pragmatism (James, 1907; Rorty, 1991). The project is largely inductive, with a deductive component. The theoretical framework of the documentational approach to didactics (DAD) includes some methodological implications that were taken into account when establishing a research design. The research design is a multiple case study (Yin, 2009), employing interviews with hierarchical focusing (Tomlinson, 1989), schematic representation of resource systems (Gueudet & Trouche, 2011) and a questionnaire app specific to the project, named Studert. The data is analyzed through thematic analysis (Braun & Clarke, 2006), combined with the use of terminology from DAD. For background information on the courses that students attended, semi-structured interviews with the course organizers were used. Data was also collected on the students' grades as well as the grade distributions within the courses. In this chapter, I will discuss the methodologies and methods that I have used and how I have used them.

On multiple occasions, I will refer to initial and eventual research design. I do this because a lot of my decisions were made with the initial design in mind and some of my eventual plans are less in line with my methodological views on research than my initial plans were. The greatest change that had to be made was that I initially wanted to collect quantitative data from a large set of students from each university. However, when I was unable to recruit a quantitatively sufficient number of students, I made the change to only use the quantitative data from the students that participated in interviews. The initial goal was generalization as well as triangulation. With the change, generalization was removed as a goal for analysis of the quantitative data. Generalization was a large part of the motivation to use mixed methods. However, even without the goal, I identify with the beliefs within mixed methods and how it and pragmatism inform research.

3.1 Pragmatism

According to James (1907), many philosophical discussions stem from different interpretations of certain words and differences of emphasis, and thus cannot be resolved. According to him, the main philosophical discussion of his day was one of rationalism vs empiricism, representing eternal principles versus observable facts. He argues that “no one can live an hour without both facts and principles, so it is a difference rather of emphasis” (James, 1907, p. 11). Instead, James introduces the pragmatic method, which is to consider every idea in terms of the practical consequences of the idea. He reasons that ideas are meant to relate different experiences to one another. They serve to help people make predictions about future experiences based on past experiences and act towards our goals based on said predictions. Whether an idea is true depends on whether the practical consequences are desirable, and since there are different views on what is desirable, there are multiple truths. He argues, that even the ‘facts’ of natural science, are merely true because they lead to successful predictions that help us act to fulfill a variety of goals that we have set. As a modern example, I would argue that one of the practical consequences of Einstein’s theory of relativity is the development of more accurate global positioning systems (GPSs). GPSs help us with goals such as finding specific locations. The theory of relativity is not just more true than previous theories on mechanics due to a greater consistency of results for a greater variety of physical situations. It is more true due to enabling a wider range of applications based on our understanding of gravity. The usefulness of GPSs is part of why the theory of relativity can be considered truer. According to James, philosophical and religious principles can also be true, in the sense that acting in accordance with them has desirable consequences (for some interpretations of what is desirable).

James sees the relationship between abstract ideas and sensible reality as two worlds which are both real and which “interact only at their boundary”. We can only truly know ideas from how they relate to our sensory experiences. In other words, the reality of ideas and the reality of the senses are too different in nature for an idea to truly correspond to an aspect of sensory reality.

I want to compare the relationship between reality and knowledge within pragmatism to geometry. When you map a cube to a two-dimensional image, the three-dimensional object of a cube is fundamentally different from the two-dimensional image. You cannot say that the two-dimensional figure *is* the cube, because it and the cube are of different natures. Consider, the three representations of a cube in figure 3.1. If you try to discuss the correspondence between the cube and the images, you will find that each image accurately portrays the shape of a cube when observed from a certain angle. In that sense, they are equally valid, but is that really a good measure of the quality of the representations. Is it not more fruitful to talk about how functional each representation is? Imagine a mathematical problem about a cube was given to three groups of people. For group A, the cube was illustrated by the representation on the left in figure 3.1, for group B by the representation in the middle and for group C by the one on the right. I would assume that the left representation would cause less confusion and thus group A would solve the problem quicker and more consistently than the other groups. Hence, I would argue that the representation on the left is more functional and thus more 'true', even though, in a mathematical sense, each representation is the result of a mathematical mapping from a three-dimensional object to a plane that is well-defined.

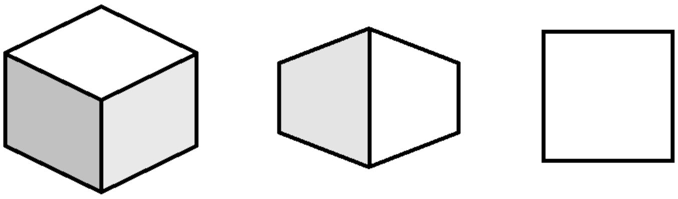


Figure 3.1: Three representations of a cube. The representation on the left is the result of a projection centered on a corner of the cube, while the one in the middle is centered on an edge and the one on the right is centered on one of the vertices.

For social science, pragmatism can establish an argument that knowledge of social reality requires interpretation. It also gives an argument for relativism, but not extreme relativism. That is, there are multiple truths, but that does not mean that every interpretation is equally true. Because truth depends on whether the consequences are desirable, and ideas about what is desirable varies, there are multiple truths. However, given an interpretation of 'desirable', the practical consequences of different ideas can be proven to be desirable to varying degrees, showing certain ideas to be truer than others.

Applying pragmatism to mathematics education, I think the following criteria can be used to determine whether a statement is true (where one can consider criteria A and B to be pre-requisites for criteria C):

A) Consistency of experience. An idea is not functional if a mathematics educator or mathematics education researcher that knows the idea keeps being surprised and confused by students' actions that the theory was supposed to help them predict and interpret. If the idea does not help relate past experiences to future ones, it is untrue.
B) Meaning. An idea must have practical consequences, in that there are differences between how an educator or researcher will act towards achieving their goals (or which goals they set) if they believe in the idea and if they do not. Otherwise, the idea has no meaning, according to James.
C) Desirable consequences. When educators or researchers do act in accordance with the idea, the consequences need to be desirable (for an interpretation of what is desirable). They need to result in students learning mathematical ideas better, that is, better enable them to use mathematics to achieve their goals in the future.

For instance, consider the concepts pragmatic versus epistemic mediation and procedural versus conceptual knowledge. In order for them to be true: A) they must enable teachers to classify students' engagement with mathematics based on the theory. B) they must enable teachers to design their instruction to focus on engagement that is both epistemic/conceptual and pragmatic/procedural, and highlights the connection between the two. C) the result of said instruction must be that the students achieve their mathematical goals during and after their education better than they would otherwise. Of course, it is still only true given a perspective on what is desirable, for instance seeing flexible mathematical skills are useful in the job market and thus considered desirable in society.

Not all ideas need to fulfill all the criteria. Similar to how natural science deals in concrete hypotheses and more general, abstract theories, there are various levels of generality of ideas in social science. Relevant to the use of resources in mathematics education, a rather specific idea may only be supposed to fulfill criterion A. It is true if it relates several concrete experiences of students' use of resources, reducing the extent to which a course organizer gets surprised and confused by how the students use resources. A more general, abstract idea about students' choice-making regarding resources is ultimately true if it helps course organizers anticipate what resources the students would use given the organizer's course design. An idea about how the use of various resources facilitate different kinds of learning is true if course organizers can use it to guide students towards the types of learning that are desirable to the course organizer, the student and society as a whole.

Pragmatism, as I see it, can easily be networked with socio-cultural theories, by emphasizing that what people consider desirable depends on socio-cultural contexts. It can be fruitfully networked with theories that acknowledges the possibility of multiple interpretations and focus on people acting towards certain goals, such as the documentational approach.

3.2 Implications of the documentational approach

In addition to acting as a lens through which teachers' practice within and outside the classroom can be interpreted, the documentational approach to didactics also provide guidelines for how to conduct studies into teachers' practice. It was important for me to consider these guidelines and reflect on which guidelines to follow, which to revise and which to dismiss when shifting the focusing from the teachers to the students. I also considered how well the principles could be followed given practical restrictions of my project and my partly inductive focus. I will present the methodological guidelines of the documentational approach here and refer back to them as I discuss the design and data collection tools I decided on. In the appendix of the original article, Gueudet and Trouche (2009) mentioned that they themselves carried out interviews in the teachers' office with an informal tone. They focused on:

1. Inventory and rationale for the documents of the current year: Which resources were used and which were the most important
2. Detailing the three most important documents: How was it produced, how were resources encountered and was anyone else involved in the planning, for instance through collegial discussion.
3. Past and future: How do they think they would have answered the question ten years ago and how do they think they would answer them ten years later.

Later on, they discuss methodological principles in general (Gueudet & Trouche, 2011). What they call *reflective investigation* involves:

- Long-term follow-up: Given the idea that geneses are ongoing processes and that schemes develop over time, the teacher needs to be studied over time.
- In- and out-of-class follow-up: Both teachers' work in class and outside class are a focus of the documentational approach, and both need to be studied.
- Broad collection: It is important to gather most of the resources teachers use that are of such a nature that they can be gathered.
- Reflective follow-up: Teachers should be closely involved in the collection of data.

Gueudet and Trouche continues by describing the data collection tools they used in the study they present in the article (Gueudet & Trouche, 2011, p. 28):

1. Logbook: The teacher describes her activity related to the classes she teaches over the course of three weeks for each year of the study.
2. Interviews and collection of resources: Three interviews over the course of the year (at the teacher's home).
3. Schematic representation of the resource system (SRRS): During the first interview, the teacher creates a visual representation of the structure of her resource system by whichever rationale she decides.

Research projects that use the documentational approach tend to use case studies (i.e. Gueudet & Trouche, 2011; Gueudet, 2014; Gueudet, 2016). In fact, Gueudet argues that they are the natural choice when conducting research using the documentational approach given the focus of DAD. She says "A quantitative study, based on questionnaires, can provide information about the resources used, but not about the schemes developed. Therefore, the documentational approach uses case studies." (Gueudet, 2016, p. 203).

3.3 Research paradigm

A research paradigm is a set of beliefs about how research should be conducted (Bryman, 2015). The beliefs include views on philosophical questions about the nature of reality and knowledge (ontology and epistemology, respectively) as well as more technical questions about how to ensure the quality of research. A paradigm has implications for researchers' questions and aims, how they collect data, how they analyze it and what form their discussion of the results takes. I adopt a mixed methods paradigm (Johnson & Onwuegbuzie, 2004). The founders primarily focus on technical questions and refers to pragmatism as its philosophical tradition. I discussed my use of pragmatism in section 3.1 (page 45), including ontological and epistemological views.

3.3.1 The paradigm of mixed methods research

The authors who coined the term mixed methods argue that both quantitative and qualitative methods are useful and that they can (and often should) be combined in a way that utilizes the strengths of either type while minimizing their weaknesses (Johnson & Onwuegbuzie, 2004). They argue against being a quantitative or qualitative purist, like positivists or interpretivists, respectively. Within both quantitative and qualitative traditions, empirical data is used, and issues of validity or trustworthiness are considered, for instance resulting in efforts to minimize confirmation bias. Within both traditions, researchers try to give meaningful descriptions of social reality derived from their data. Johnson and Onwuegbuzie criticize positivists for failing to properly account for the decisions that researchers make in the course of the research and qualitative researchers for adapting positions that are strongly relativistic. They argue that most researchers are soft relativists, acknowledging the possibility of multiple interpretations while also acknowledging that some aspects of social reality function as external to people. For instance, while what side of the road to drive on is theoretically a social rule that has been decided by a society of individuals, in practical terms, it functions more like a social fact external to the individual since the individual has minimal power to rebel against it. Johnson and Onwuegbuzie think that qualitative researchers ought to provide more rationale for their interpretations of data. Essentially there can be a lack of transparency of the reflections made by the researcher.

Johnson and Onwuegbuzie builds mixed methods on a selection of ideas that they believe few researchers would disagree with whether they are proponents of quantitative or qualitative methods in social research:

a) Relativity of “light of reason”. What people consider ‘common sense’ varies between persons.
b) Theory-laden perception. Observations are not a perfect window into ‘reality’. What we notice and how we interpret it is based on our background, knowledge and experience (including knowledge of theories).
c) Underdetermination of theory by evidence. The same data can be interpreted using multiple theories without contradicting any of them.
d) A hypothesis cannot be tested in isolation. Assumptions must be made to design a test, these assumptions belonging to a holistic network of beliefs. Even if the hypothesis passes the test and can fit within the network of beliefs, other possible explanations will exist.
e) The problem of induction. All evidence is probabilistic, nothing can be inductively proven as a universal social fact.
f) Social research is a social enterprise. Researchers are part of a social context and act according to attitudes, values and beliefs that they hold.
g) Inquiry is value-laden. Researchers can never fully negate their values when designing scientific inquiry.

Johnson and Onwuegbuzie do not aim to philosophically bridge the ontological and epistemological differences that lead researchers to quantitative or qualitative purism. As they identify with pragmatism, they see the practical consequences as more important. In order to determine the practical benefits of using a mixed methods approach, Johnson and Onwuegbuzie lists several strengths and weaknesses of quantitative and qualitative research, demonstrating that several of the weaknesses within one tradition are among the strengths of the other. For instance, the weaknesses of quantitative research include:

- Because of the deductive nature of quantitative research having to decide all the factors to measure in advance, the opportunity to discover phenomena related to other factors and generate new hypotheses based on them is limited.

- The knowledge it produces may be too general and abstract to have practical applications in society.
- The researcher's categories and theories may differ from the understandings of the participants.

Qualitative research on the other hand, can include studying a few cases in great depth, providing ample opportunity for observing new phenomena and forming new theories based on them. It can be specific and locally situated, greatly increasing the chance of making discoveries that can have practical consequences in local communities. The data collection in qualitative research concerns itself with the understandings and perspectives of the participants. On the other hand, the weaknesses of qualitative research include:

- Lack of insight into how generalizable the results may be.
- Difficulty of testing hypotheses.
- Time-consuming collection and analysis of data.
- Results can easily be influenced by the researcher's biases.

Quantitative research fairs better on these fronts. Data is collected on a wide range of people, making it possible to investigate generality. If designed well, quantitative methods can be well equipped to test hypotheses. Quantitative analysis involves using statistical models, which have the potential to minimize the effects of personal bias when interpreting the data. The data collection and analysis can also be faster within quantitative research. However, it should be noted that since mixed methods proposes using both quantitative and qualitative methods, it is likely to be more time-consuming than simply using qualitative methods. Johnson and Onwuegbuzie also admits that other weaknesses of mixed research may include that the researcher needs to study up on a wider range of methods, that it can be hard to carry out multiple methods concurrently, particularly for a single researcher, and that several practical problems on how to analyze various forms of data is left to the researcher.

Johnson, Onwuegbuzie and Turner (2007) notes that many have argued for using multiple methods before the term mixed methods research was coined. For instance, several authors encourage between-method triangulation to eliminate biases (or errors in the conducted research) from the individual sources of data. Investigating multiple definitions of mixed methods research in (at the time) recent studies, they suggest a general definition:

> Mixed methods research is the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g., use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the broad purposes of breadth and depth of understanding and corroboration. (Johnson et al., 2007, p. 123)

They also say that one can have mixed methods studies, but one can also have mixed methods research programs, where either some of the studies within the program are mixed, or where it includes both quantitative and qualitative studies.

In the same article, the authors argue that mixed methods studies can be labelled "Pure" mixed, qualitative mixed or quantitative mixed based on whether the quantitative and the qualitative methodologies of the study are considered of equal status within the study or one type of methods is of more importance than the other.

3.3.2 My use of mixed methods

In my project, the original intent was for the types of methods to be more equal in status, the way it turned out, the study is qualitative mixed. Leech and Onwuegbuzie (2009) detail a typology of mixed methods research design and for each type, they give an example of a study using it. They conclude that there are eight different research designs, one for each combination of answers to the following three questions.

1. Partially or fully mixed. A study is fully mixed if quantitative and qualitative aspects are present in the research aims, data collection methods, analysis and type of inference. Only mixing quantitative and qualitative in a few aspects make it partially mixed. For instance, if one collects qualitative and quantitative data, then qualitatively analyze the

qualitative data and quantitatively analyze the quantitative data it is partially mixed. For it to be fully mixed, one should also analyze qualitative data quantitatively and quantitative data qualitatively.

2. Concurrent or sequential. Are the quantitative and qualitative collection of data deployed concurrently or is one collected prior to the other.
3. Equal or dominant status. Is one of the types of data more central to the focus of the study, or are they treated as equally significant.

Leech and Onwuegbuzie also present a more common typology that is used more often, and that only considers the last two questions. It uses the symbols "+" and "→" to symbolize concurrent and sequential (respectively) and uses capital letters to highlight which type of methods have the higher status. With the first typology, I will argue that my project is a fully mixed, concurrent, dominant status design. With the second typology, my research design would be considered QUAL+Quan since it is concurrent and qualitative methods are more central. It was initially supposed to be QUAL+QUAN.

My project is fully mixed because there are both qualitative and quantitative aspects to my research questions, data collection tools and analysis methods. For instance, my first research question (resources used and to what extent) has a more quantitative focus, whereas my second research question (schemes developed) is more qualitative in nature. The Studert app is a quantitative data collection tool, while the interviews and the SRRSs are qualitative. While thematic analysis is a qualitative methodology, I have incorporated quantitative elements into it, such as counting the statements related to a theme. I also qualitatively analyze some of the Studert app data.

Kelle and Buchholtz (2015) describes the benefits of mixed methods as follows: "Quantitative methods can give an overview about the domain under study and can describe its heterogeneity, whereas qualitative methods can be used to gain access to specific knowledge in the field (…)". As previously discussed, this was my intent when I intended my study to be pure mixed. However, mixed methods can be used in multiple ways, corresponding to different aims of the research. In their discussion of a typology of mixed methods sampling designs, Onwuegbuzie and Collins (2007), also mentions five reasons to mix methods. What Kelle and Buchholtz describes is called complementarity, and the other reasons are triangulation, development, initiation and expansion. While I initially intended to use mixed methods for complementarity, I ended up using it for triangulation. Onwuegbuzie and Collins specifically mention that a concurrent research design should be used when the goal is triangulation. Concurrent versus sequential design is one aspect of their sampling typology. The second is the relationship between qualitative and quantitative samples, which can be:

1. Identical. Quantitative and qualitative data is gathered on every participant in the study.
2. Parallel. Quantitative and qualitative data are gathered on different participant, but within the same "population of interest" (as defined by your research focus).
3. Nested. The participants that you collect one type of data on are a subset of the participants that you collect the other type of data on.
4. Multilevel. Quantitative and qualitative data are gathered on different participants from different populations of interest (for instance qualitative data on teachers and quantitative data on students).

My initial plan was for a nested design, but after making changes, the study uses the identical sampling design.

3.4 Research design

In my project, I used the research design of a multiple case study (Yin, 2009). The data collection was carried out during the autumn semester of 2017. A total of nine students from three different Norwegian universities were involved in the study. The data collection involved interviews using hierarchical focusing (Tomlinson, 1989), schematic representations of resource systems (Gueudet & Trouche, 2011) and the questionnaire app Studert, which was designed for the project.

I chose a multiple case research design based on the methodological guidelines of the documentational approach and based on my view that examining students from different contexts could give insight into the role of the context and thus have a lot of theoretical value. It could lead to forming hypotheses about what features of the differences between the university courses facilitated the differences observed, which in turn would lead into a discussion about the degree to which the context affects the students. I also reasoned that if I saw similar results between different universities, then it would increase the chance that what I observed were general issues, at least within the national university context.

3.4.1 Multiple case studies and my use thereof

Yin (2009) defines case studies as follows:

> 1. A case study is an empirical study that:
>   - Investigates a contemporary phenomenon in depth and within its real-life context, especially when
>   - The boundaries between phenomenon and context are not clearly evident […]
> 2. The case study inquiry
>   - Copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result
>   - Relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, and as a result
>   - Benefits from the prior development of theoretical propositions to guide data collection and analysis. (Yin, 2009, p. 18)

I think a case study design was a good choice for my project, considering how well it fits this definition. I admit that as far as studying the phenomena of students’ use of resources in their real-life context, my study does not deliver fully. Observation of study sessions would have been a natural choice. I chose not to use it given practical concerns about the time it would take to collect and analyze the data given the number of participants I had in mind for my study. I considered interviews to be a sufficiently accurate source of data. I did, however, decide to conduct the interviews on campus, so they would not be too far removed from the context. Yin also mentions that case studies do not necessarily need to include direct observational data. I am convinced that the university context greatly affects the students’ resource use and that studying the latter without consideration of the former would not be useful. I will also argue that there are many variables of interest to my inquiry, I used multiple sources of evidence and to some extent, used theoretical propositions to guide data collection and analysis.

Yin argues that case studies are particularly suited for research where contemporary events are studied with no need to control for behavioral events, and when the research questions involve matters of “how?” or “why?”. He also says that several methods are possible within a multiple case research design. He lists surveys as a method particularly suited when contemporary events are studied with no need to control for behavioral events, and when the research questions involve matters of “who?”, “what?”, “where?”, “how much?” and “how many?”. Most of my research questions involve how and why, while some involve what and how much. Questions are the first of five components of a research design that Yin mention as particularly important for case studies. The components are (Yin, 2009, p. 27):

1. The study’s questions
2. The study’s propositions
3. The unit of analysis
4. The logic linking the data to the propositions
5. Criteria for interpreting the findings

While most of these questions will be answered along the way, I will establish my unit of analysis in this section, as Yin argues that it is important to establish what each ‘case’ in a case study is. He argues that the unit of analysis should not be a person, since that would imply that you are interested in everything about the person. He says that among other things, the word case has been used about “decisions, programs, the implementation process and organizational change” (Yin, 2009, p. 27). The unit of analysis need to establish the boundaries of ones focus. My unit of analysis is *Students’ interaction with resources within the context of a university mathematics course.* Based on it, each case will be a single student’s interaction with resources within the course they are taking.

Propositions can be understood as assumptions you use in order to create your resource design. I will discuss the reasoning behind my choices as it comes up. However, I will make one example here. I made a decision to study students throughout a first semester course at university. I chose to follow students over a semester based on the proposition that students’ documents developed over time, so it would be less theoretically valuable to study a student at a single point in time. I did not study them for longer than a semester based on the practical proposition that I would have a hard time finishing my project within the given time frame if I did. I chose the first semester at university based on the proposition that I assumed the students' documents would develop the most during that semester as a result of secondary-tertiary transition. Thus, I thought this choice of time frame would give me the most theoretical value within the practical constraints of my project.

The benefit to theories is an important goal behind using case studies. Yin admits that generality is hard to establish based on a single case study and argues that the objective of case studies is to expand upon theories rather than to "enumerate frequencies" (Yin, 2009, p. 15). This is the case even when you consider a multiple case study. Yin mentions that the most common rationale for using a multiple-case design is replication. The goal shaping the design is "the development of a rich, theoretical framework. The framework needs to state the conditions under which a particular phenomenon is likely to be found" (Yin, 2009, p. 55). Most multiple-case designs focus on multiple cases that fit the same criteria, and thus, according to the working theory of the researchers, they are expected to yield the same results. However, Yin also acknowledges that multiple-case designs can be more complex.

> Multiple-case rationales also can derive from the prior hypothesizing of different types of conditions and the desire to have subgroups of cases covering each type. These and other similar designs are more complicated because the study should still have at least two individual cases within each of the subgroups, so that the theoretical replications across subgroups are complemented by literal replications within each subgroup. (Yin, 2009, p. 59)

My rationale for using a multiple-case design is to investigate the influence of certain factors. I want to derive differences through inductive data analysis. The different factors correspond to differences between the mathematics courses the students take at different universities, and will be discussed further in the next subsection. The wording of Yin's descriptions of multiple-case design may seem to imply a deductive approach, while my approach is primarily inductive. However, a deductive approach is not an inherent feature of case studies. In fact, Bryman (2015) contends that case studies with predominantly qualitative strategies tend to have an inductive approach.

Yin warns against incorrectly using the term multiple-case. He gives an example about studying nine schools. If you pool the results from the students to quantitatively analyze data across all nine schools, it is no longer replication and no longer a multiple-case design. Instead, it is a single case, where the case is certain aspects of the school system. It is only considered multiple-case if each school is considered individually, and then compared to see if results were replicated. I will on the one hand, discuss each student individually, and then, using thematic analysis, compare and contrast students within each university and across all three universities. I do think I will focus on the latter a bit more than Yin would approve of. However, from the perspective of pragmatism, I consider my approach to be quite beneficial given the aims of my research.

3.4.2 Sampling and recruitment

I chose the universities and courses based on the following criteria:

1. They were all Norwegian universities.
2. All the courses were introductive mathematics courses for engineers, which involved calculus (the extent to which they also involved geometry or linear algebra varied).
3. They emphasized different resources. One was more focused on traditional material resources (University Alpha), one on digital resources (University Beta) and one on social resources (University Charlie)

Beyond those criteria, universities were chosen using convenience sampling (Bryman, 2015). The third criterion constitutes the differences between the contexts that I hoped would lead to theoretically significant differences in the results. While I will cover the differences between the universities in more detail in the results, figure 3.2 includes the resources that were emphasized in each course. The figure is part of a poster I presented at CERME11 (Hillesund, 2019).

Students were recruited in person. I gave a presentation about the project in the middle of a lecture. After the presentation, students signed up and received an information document about the project as well as a password and QR-code to access the Studert app. When they signed up, students indicated whether they wanted to participate in interviews and whether they gave permission to access their grades. My plans for recruiting students were as follows:

- Anyone who signed up to use the Studert app would be accepted.
- Fifteen students from the smallest course and thirty from each of the larger courses was considered as necessary to have a solid quantitative basis. Otherwise, the app data on the interview participants would be used.
- Up to five students from each course would be accepted as participants in the interviews.
- At least two students signing up for interviews would be required. If a course had less than that, it would be removed from the study.
- In the event that there were more than five students from a course that signed up for interviews, I would try to use theoretical sampling (Bryman, 2015) based on the app data of the first two weeks. If I was unable to identify any themes from the data at that point, I would prioritize getting at least two participants of each gender (if possible) and beyond that, sample randomly.

The recruitment process resulted in an insufficient number of app participants, and a number of interview participants that was sufficient, but did not exceed the maximum and hence did not necessitate further sampling. Not all students who signed up for interviews ended up participating, but all students who completed the first interview, completed their participation. As shown in figure 3.2, the student recruited were two male and two female students from University Alpha; two male students from University Beta and two male and one female student from University Charlie. The students were all given both a pseudonym and a short code. The short code was the first letter of the pseudonym of their university followed by a number (i.e. A1, A2, A3 and A4 for students from University Alpha). The pseudonym was chosen such that the first letter of the pseudonym corresponded to the first letter of the university's pseudonym. Beyond that, the most popular Norwegian children's name starting with those letters (between 2007 and 2016) were used, resulting in the pseudonyms in figure 3.2.

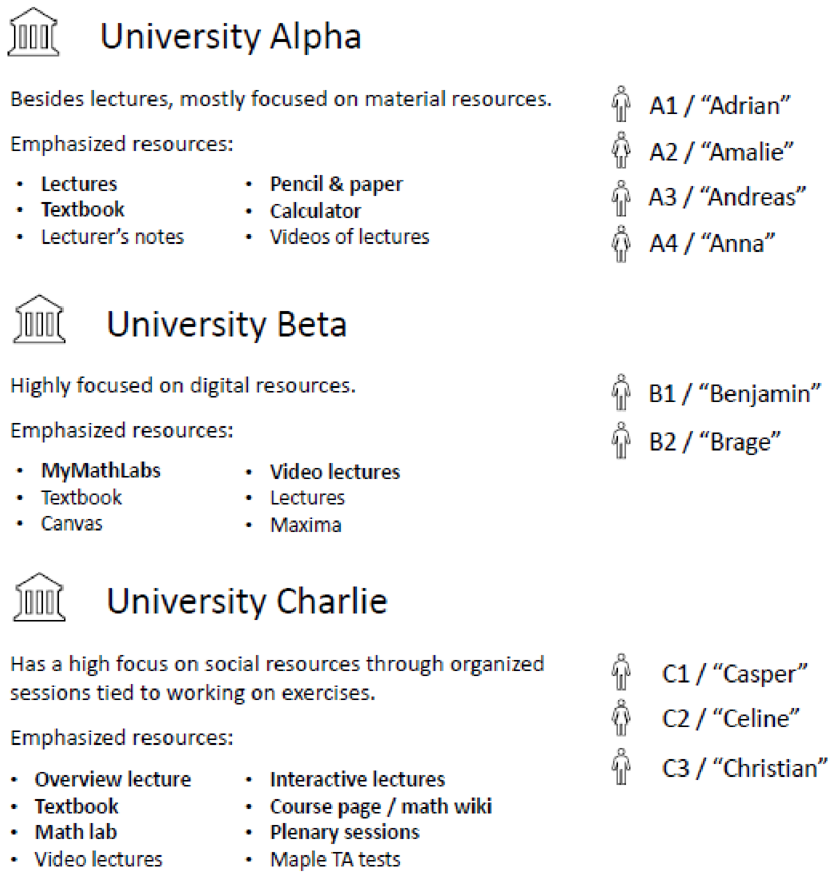


Figure 3.2: From poster for CERME11 (Hillesund, 2019). Three universities were chosen and a total of nine students. The figure shows the gender, code and pseudonym of the students and which resources were emphasized in each course. The resources that seemed particularly central to the courses are in bold text.

While I intended to focus on students during their first semester at university, the course at University Beta included both students in their first and second year (first and third semester). Both the participants who volunteered were in their third semester.

3.5 Data collection tools

The three main sources of data were semi-structured interviews using hierarchical focusing, schematic representation of resource systems (SRRSs) and the Studert app. In addition, I collected contextual information through semi-structured interviews with the course organizer for each course (who at Universities Alpha and Beta was also the lecturer). I took field notes during the first visit at each university (for recruitment) and during the first interview with every student, or course organizer. After the completion of the course, I got information from them on the grade distribution in the course from the course organizer as well as the grade of the participating students that had given permission to use their grade. I conducted a pilot interview to test the methods hierarchical focusing and SRRSs. The Studert app was not piloted, because there was not enough time between its creation and its implementation.

I chose to use hierarchical focusing because it was designed to limit the extent to which the researcher co-produces the answer to a question in order to combat confirmation bias (Tomlinson, 1989). I chose to use SRRSs because they are mentioned in the documentational approach and due to benefits I witnessed during the pilot interview. The pilot student seemed more relaxed after the task of constructing a mind map and was able to better structure his reflections on his use of resources. I chose to use the Studert app because of the initial focus on generalizability. I chose thematic analysis because I considered it a good inductive approach that was designed in such a way that it can be combined with theoretical frameworks.

3.5.2 The method of schematic representations of resource systems

A schematic representation of resource system (Gueudet & Trouche, 2011) is a form of concept map that is specifically concerned with someone's resource system (as defined in the documentational approach). An SRRS can be structured in any way that the participant sees as meaningful. Gueudet, Pepin and Trouche (2013), for instance, found that two teachers structured their SRRSs quite differently. The structure of Vera's SRRS (Gueudet et al., 2013, p. 1008) showed where she kept the resources (see the top of figure 3.4). Inga split her SRRS into two parts (Gueudet et al., 2013, p. 1010), one for lesson preparation (bottom left of figure 3.4) and one for communication with students and parents (bottom right of figure 3.4).

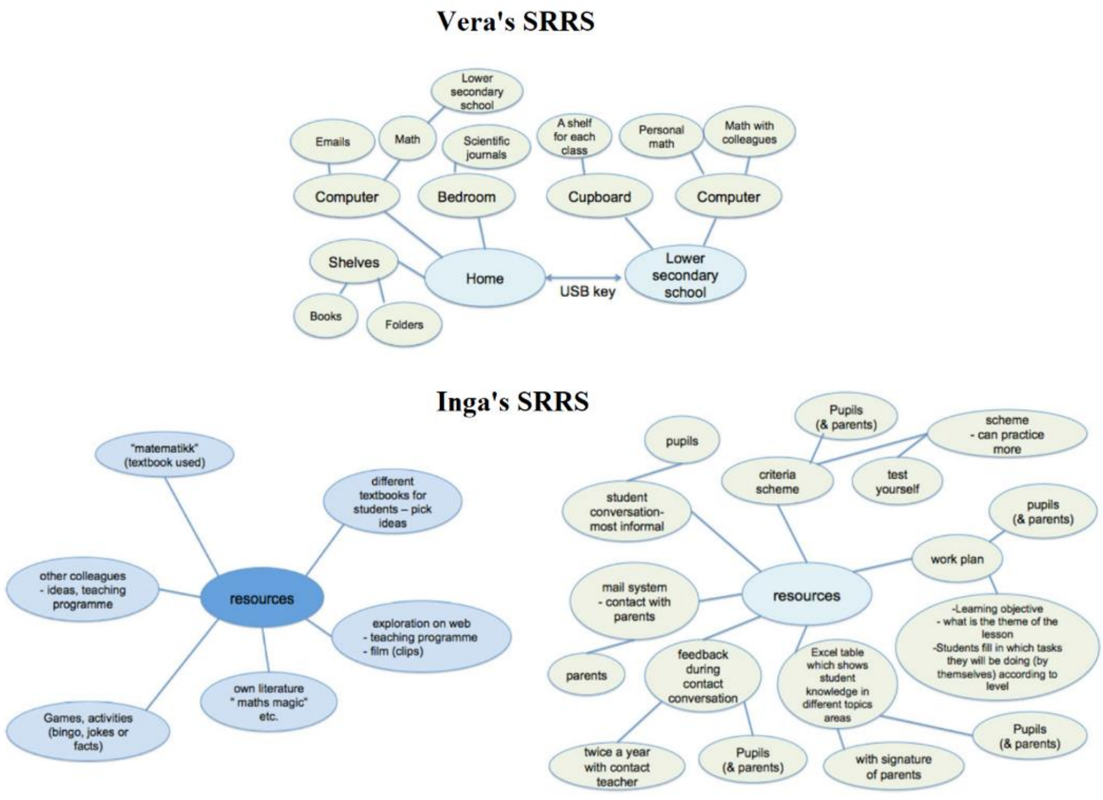


Figure 3.4: How two teachers structured their SRRSs differently. Vera's structure is based on location of resources. Inga's SRRS is split in two. The left part represents the resources used to prepare lessons and the right part represents resources used to communicate with pupils and parents. Figure obtain by combining parts of two figures from Gueudet and colleagues (2013).

Beyond an SRRS needing to be a visual representation of someone's resource system, Gueudet and Trouche does not give any further instruction. I believe the task is left intentionally open for the research participant to interpret.

3.5.1 The method of hierarchical focus interviewing

Interviews using hierarchical focusing (Tomlinson, 1989) are designed to limit the extent to which the interviewer co-produces an answer, while still keeping the interview semi-structured (Bryman, 2015), rather than unstructured. Another aim is to limit the instances of the interviewer imposing terminology upon the interviewee. As such, the interviewer should try to use terminology introduced by the interviewee whenever possible. In hierarchical focus interviews, one asks open, general questions. For each question, one has several sub-questions that the interviewee may answer spontaneously through their answer of the more general question. If needed, the interviewer leads the interviewee towards increasingly specific questions, through non-directive strategies such as asking the interviewer elaborate on something they said. Once a line of inquiry has been exhausted, the interviewer returns to the most general question or topic that the interviewee has not covered yet and starts the process of increasing specificity again.

Tomlinson describes hierarchical focusing as a research interview strategy by listing the five points below (Tomlinson, 1989, p. 162). Some of them can be considered general rules that would apply to most interview strategies, but the third and fourth point are particularly central to hierarchical focusing.

1. Conduct a thorough literature review and describe the field of research as you see it.
2. Decide on your research focus and what aspects and elements of the topics you want the interviewee to talk about.
3. Create a visual portrayal of said aspects and elements, including a skeleton of the structure to use as a guide and record.
4. Carry out interviews as open-ended as possible, using non-directive strategies. Record the interviews.
5. Make a verbatim transcript for analysis.

The “skeleton” mentioned in the third point is later referred to as an “agenda of actual questions, arranged hierarchically” (Tomlinson, 1989, p. 165), which I will refer to as the interview agenda. To conduct a hierarchical focus interview, the interviewer should prepare an agenda of questions and topics that ought to be covered. A spontaneous answer is considered stronger than a prompted answer, as it indicates that the answer is considered relevant by the interviewee, and since the interviewer cannot be accused of co-producing the spontaneous answer. Thus, it is important to hierarchical focus interviews that the interviewer notes whether the interviewee was prompted to answer a question, or did so spontaneously. It is recommended to include check boxes in the interview agenda to keep track of what has been covered and whether the interviewee answered a sub-question spontaneously or prompted. Figure 3.3 shows part of an example from the original article (Tomlinson, 1989, p. 166).

Tomlinson makes it clear that hierarchical focusing is founded in constructivist thinking. However, as I see it, the methodology is mostly concerned with reducing the extent of confirmation bias, and as noted by Johnson and Onwuegbuzie (2004), the desire to minimize confirmation bias is among the goals that are shared among all types of research.

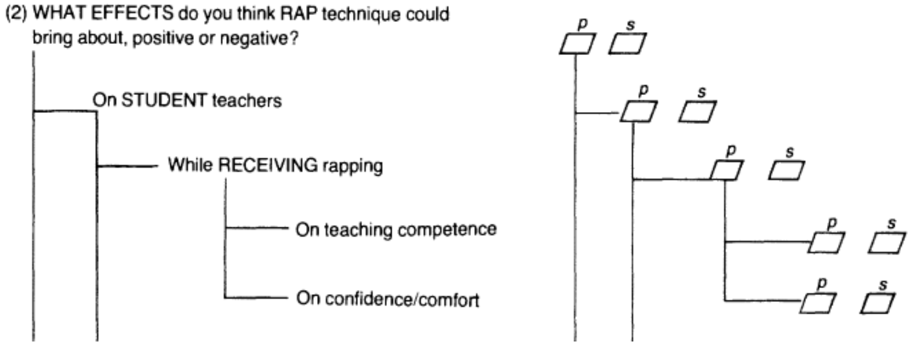


Figure 3.3: Part of an example of an interview agenda for a hierarchical focus interview (Tomlinson, 1989, p. 166). The questions have a hierarchical structure and the interviewer keeps track of which questions were answered spontaneously or in response to prompting.

3.5.3 The pilot interview and lessons learned from it

I carried out a pilot interview at the end of February 2017. I interviewed a mathematics student (in the middle of his second semester) at my own institution using hierarchical focusing and schematic representation of resource systems. The student in the pilot interview will be referred to by the pseudonym “Per”. The purpose of the pilot interview was to:

1. Practice conducting an interview using hierarchical focusing.
2. Evaluate the use of hierarchical focusing to decide whether to use it in the actual study. Identify issues to keep in mind if I decided to use it.
3. Have Per’s answers in mind when making final decisions on the interview questions in the study.
4. Evaluate the use of schematic representations of resource systems to decide whether to use it in the actual study. Identify issues to keep in mind if I decided to use it.

In the first part of the interview I asked how much Per studied mathematics; in what different ways he studied it; which resources he used for each way of working; which resources he used in different situations; to what extent he used emphasized resources and if there were resources he had found himself or been recommended. The amount to which he worked with others was a question I had that he touched on spontaneously when answering about ways of working, so I simply asked him to elaborate. I also asked him to elaborate on some of the resources he mentioned. For instance, when asked how he used resources in different situations, he mentioned Khan Academy and YouTube as supplements to lectures when he felt he needed it, and I asked him to elaborate. In his elaboration, he said he used Khan Academy a lot to prepare for exams and that he appreciated that the videos explained the topics in a “basic” way.

After the first part, I asked him to construct a *mind map* based on the different situations and resources he used in those situations. In the Norwegian school system, students are taught about mind maps as ways to organize your thoughts by using text bubbles and lines between them to show the relationship between ideas and objects. This resulted in the SRRS in figure 3.5. Similar to Inga (Gueudet et al., 2013), Per split his mind map in two based on two different purposes that he used resources for.

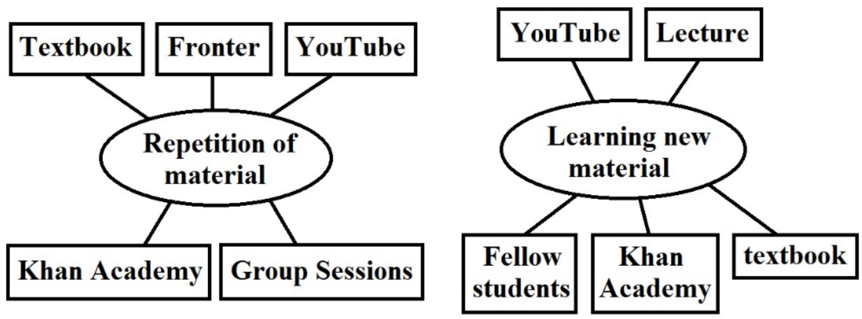


Figure 3.5: SRRS of the mind map that “Per” constructed during the pilot interview. He decided to structure his mind map based on what resources he used for repetition and what resources he used for learning.

After the mind map construction, I asked him to explain the rationale of his mind map. In the second part of the interview, I inquired into whether he felt particularly skilled at using any resources and how he chose what resources to use. I asked a follow-up question to his description of the mind map, asking whether his work on exercises (which he had previously mentioned) was included in repetition. He answered that it belonged to both halves of the mind map, saying "I think that, you work with exercised to learn it, right… the new material as well." Another interesting answer was that he said he decided on what resources to use based on how difficult he found it, mentioning a specific channel on YouTube he went to if he felt like he did not understand the "basic concept" of a topic.

Identifying issues relevant to the use of hierarchical focusing: I found that Per hardly answered any of the sub-questions I had prepared spontaneously. However, I did find that the openness of the questions led to discussion of aspects of resource use that I had not prepared questions for. As an example, he divided his resource use into learning and repetition of mathematical content during the interview. I felt like it gave me more insight into how he thought about his use of resources. As such, I reasoned that the use of hierarchical focusing was useful, even if there were fewer spontaneous answers to sub-questions than participated.

Implications for interview questions: The focus on the amount of time spent working was never intended for the interviews in the study, as I reasoned that I would be able to see it myself from app data. After the pilot interview, I decided that the question about ways of working was too leading and too similar to the question about different situations. I scratched the focus on the students' skill with certain resources, replacing it with a question about whether there were any resources they felt like they had made their own. Since Per described many features he liked about the resources he used, I decided to add a focus on which resource the students' liked and whether that affected their use of said resource.

Identifying issues relevant to the use of SRRSs: Upon reflection, I realized that the structure of his mind map may have been influenced by how I phrased the task description. I had told him to make the mind map about the situations and the resources he used within them. He had then created a mind map with two situations and multiple resources tied to each situation. I wanted the task to be more open-ended. I decided that in the actual study I would consistently phrase the task as follows: "I wondered if you could make a mind map about how you use resources to learn mathematics". Another issue I identified related to the quality of answers in the second part of the interview compared to the first. Per gave longer answers to the questions. Prior to construction, he had a tendency to pause in the middle of a sentence to consider what to say next, while it seemed like he knew what he wanted to say during the second part of the interview. I theorized that the task of constructing a mind map had given him an opportunity to ‘collect his thoughts’ regarding his use of resources. Based on this, I decided to move up the construction of mind maps to the start of the first interview for each student in the study.

3.5.4 Implementation of interviews with hierarchical focusing

I conducted three interviews with each student, with the exception that the second interview with A2/Amalie had to be cancelled due to illness followed by difficulty of rescheduling. Each interview took place at the campus of the university in question. The first interviews took place three to four weeks into the semester (late September, 2017). The time between interviews at a given university varied from four to six weeks, with the exception that the third interview with students from University Charlie had to be postponed to the start of the next semester. For students from universities Alpha and Beta, the third interview took place early in the ‘exam period’ (early December, 2017). I created one interview agenda for the first round of interviews. I have since translated it to include as Appendix A (page 293). For subsequent interviews, I had general interview agendas, but some questions were individualized based on the students’ answers from previous interviews.

I was conscious about the interviews being partly deductive and partly inductive. The intent for all the interviews was to go in with certain research foci, yet be open to devote attention to what the students chose to focus on. Some research foci were added to the interview agendas of upcoming interviews with all students because a student brought them up in an interview and I found it interesting. I applied a few general principles to the interviews:

- Rather than use the same formulation of the question to all students, try to use terms introduced by the student. If the students have not introduced any terminology, try to use layman’s terms.
- Be open to ask follow-up questions or simply ask them to elaborate.

- Be open to ask follow-up questions about topics that were not originally part of the research foci.
- If a student asks if something can be considered a resource, always answer yes.
- If a student asks if something is included in the question, always answer yes.

As an example of the latter: When I asked Benjamin to describe how the course was organized, he asked if the question included his opinion on said organization, and I said yes. I had not planned for it to be included in the question, but was intrigued when Benjamin interpreted it that way.

I will present an overview of the interview agenda for each round of interviews. Note that my formulations in the upcoming paragraphs do not correspond to how I phrased the questions in the interviews.

The first interview: After greeting the students, I ask them to construct a mind map about how they use resources to learn mathematics. Once they have completed it, I ask them an open question about how they use resources to learn mathematics. The formulation is always “Can you tell me a bit about how you use resources to learn mathematics”. Potentially, I ask follow-up questions. Other research foci of the first interview include which situations cause the student to use resources differently and how; to what extent they use resources emphasized by the university and how they discovered additional resources; whether there are any resources they feel like they have made their own; whether there are resources that they like or dislike and if it affects how much they use it; whether they use resources differently depending on the mathematical topic; whether and how much they ask questions of lecturer or other university staff; how often they work with fellow students; how many they work with when they do and whether they use resources differently when working with others compared to working alone. Lastly, I ask the student to describe their mind map. However, in the event that the interview goes long and the students appear exhausted, I consider dropping it. It should also be noted that if the student asks for clarification on what is meant by “making a resource your own”, I ask if there are resources that they have found ways to use that they were not taught by anyone.

The second interview: Prior to the interview, I prepared summaries of the student's answer. I start the interview by presenting a summary of the students' general strategies, including resources used and situations that affected the use of resources. I ask them how accurate the summary is and whether any part has changed since the previous interview. Afterwards, I inquire specifically into whether they use any new resources or use any resources more or less than at the time of the previous interview. I inquire into whether any part of their strategies for how to use resources has changed. I ask them to elaborate on any changes by discussing what caused the change and whether the change is temporary. I proceed to give a summary of any resources that they reported feeling like they had made their own and ask if they have anything more to report this time. Then I give a summary of their use of social resources, and ask them how accurate it is and whether there have been any changes to report. As with general strategies, I ask them to elaborate on any changes. Afterwards, I move on to ask them to describe the organization of the course. If they ask for clarity or if they do not address it spontaneously, I ask them what resources are provided or emphasized; what mandatory assessment is part of the course and what the organized sessions of a normal week are. If they do not spontaneously mention them, I specifically ask them whether any digital learning platforms are used, consistently using Fronter and Canvas as examples (as it is my impression that Fronter had been the most popular platform in the Norwegian school system, but at the time many institutions had recently transitioned to Canvas). Lastly, I hand them a digitally constructed representation of their mind map. I ask them if they would like to make any changes to it, and if so, if they could talk about the changes.

The third interview: I begin the interview by giving the student a digitally constructed representation of their mind map from the second interview and asking them to discuss any changes they would like to make. Then, similarly to the second interview, I ask the student about changes to their use of resources and general strategies; what resources they feel like they have made their own and their use of social resources. This time, however, I do not present summaries. Prior to the interview, I ask them to bring a specific resource to give an example of how they use it. At this point in the interview, I ask them to present said example and the use of said resource. Afterward, I move into a hypothetical question about resources for assessment, which I will describe a few paragraphs below this. Lastly, I ask them a few questions about their experiences participating in the study.

The intent behind the summary was to check whether my interpretation of the students' statements was not too far removed from what they had meant to communicate with these statements. I also considered it a possibility that simply asking them whether there had been any changes to their use of resources could be unproductive. If they did not recall what they said in the previous interview, some changes could have gone unreported. However, I became concerned that I let my interpretations set the tone for the second interview, so I did not include it during the third interview.

For each student, I chose what resource I asked them to present based on a few criteria. It had to be a resource that they mentioned using; it had to be a resource that I interpreted as being more significant to them than to the other participants and if there were multiple resources fitting the two criteria above, I would pick the one that seemed the most significant to them.

The assessment hypothetical was inspired by a statement that A4/Anna made during the first interview. She said she only used solution suggestions to check whether she had the right answer. I was intrigued because multiple students mentioning resources related to assessment, without going into how and why. I was curious about what students looked for in assessment resources and if, given the chance, most students would only check whether their answer was correct, and not, in the case of error, what the correct answer was. Since the answers in a textbook could not provide that option, the hypothetical question was about an imagined computer aided assessment program. I asked them how much they would use each of the following options when solving mathematical problems with such a program:

A. Ask the program to tell you whether your answer was correct or incorrect
B. Ask the program for the correct answer
C. Ask the program for a hint
D. Ask the program for a detailed solution of the problem

I failed to properly communicate that since it was a hypothetical, I wanted them to imagine an ideal program that gave good hints and never reported a false negative due to syntax errors.

All the interviews were audio-recorded. Afterward, they were transcribed using the transcription scheme detailed in Appendix B (page 294). At the end of the thematic analysis, I picked a selection of excerpts to translate into English. They were picked to represent the various themes identified. The length of the interviews varied based on how much the student shared. To illustrate the differences, table 3.1 shows the combined word count for each student. I calculate them by marking all their statements from all their interviews in a Microsoft Word document, and rounding it off to the nearest hundred. The word count ranged from 3400 to 7100 for students who participated in all three interviews, while Amalie, who only participated in two interviews, had a word count of 2000.

Student	**A1**	**A2**	**A3**	**A4**	**B1**	**B2**	**C1**	**C2**	**C3**
Word count	6800	2000	4400	3400	7100	6300	3800	3500	5000

Table 3.1: The approximate word count for each student when summing up their answers throughout all three interviews (or two, in the case of A2/Amalie).

3.5.5 Implementation of schematic representations of resource systems

As mentioned above, I asked students to construct a mind map during the first interview, and gave them a chance to edit it during the second and third interview. I introduced the task during the first interview by asking them to create a mind map about how they used resources to learn mathematics. Amalie was the only student to ask for more information as she asked what should be in it. I answered that it was up to her, but should at least include the resources she used. Her mind map only included resources.

I use ‘mind map’ to mean the visual representation that the students wrote by hand. Based on the mind map, I translated the elements to English and created digital representations of them, which I will refer to as the ‘schematic representations of their resource systems’ (SRRSs). Because students structured their mind maps differently, I decided to make the differences immediately apparent in the SRRSs by colour-coding the elements. I used red for the element that functioned as a headline (which all the students had), blue for resources, darker blue for resource categories, green for situations, purple for purposes and gray for any other type of element. I included explanation of the colour-coding at the bottom of every SRRS. At the top, I included which student it represented and which interview it was based on. Further detail on how I translated elements and constructed the SRRSs are included in Appendix C (page 296).

While all nine students constructed a mind map during their first interview, the degree to which they made changes when they were given the opportunity varied. Three students made no changes to their mind map, four changed it during one of the subsequent interviews and two changed it during both the subsequent interviews. In total, the 26 interviews resulted in 17 different SRRSs. They are all included in appendix K (page 407).

3.5.6 Data collection using the Studert app

The Studert app was developed for the project during the summer months of 2017. There were two versions of the application, one for Android devices and one for Apple devices. Within it, students were supposed to fill in information for every study session related to mathematics. The rationale for using it, rather than simply a questionnaire included:

- The issue of recollection: On the question of how often a student uses a resource, they may not have an accurate estimate and may guess. Gathering quantitative data on every study session would lead to a more accurate estimate.
- Generalization: The app was initially intended to be used on a wider sample to try to identify trends in the use of resources.
- Triangulation: The data gathered from the app may shed more light on several statements that students make about their use of resources.

All these purposes could be fulfilled by other forms of quantitative data collection. The rationale for developing an app, included.

- Quick for the student to fill in. An effort was made to design the app to remember previous answers from the same student and suggest them when the student started writing the word.
- Convenient to use. Students only needed a smart phone to fill in the information, which they carried around anyways.
- Less work for the researcher. The data would be automatically stored digitally, so the researcher would not have to manually enter them into a program. Each answer would also automatically get a number associated with it in the app.
- Possibility to investigate new questions. With an inductive approach, I was open to adding unforeseen foci to analysis. Given that every answer would get a number associated with it, it would not be difficult to code simple programs that checked for every instance of answer X to questions Y and check for correlation with answers to other questions. For instance, I could make a program to investigate what resources students used when they studied at home compared to when they studied on campus.

I had also hoped that filling in information after every study session would be easy to turn into a habit and combined with the process of filling in information being quick, students would not experience their participation as too much work.

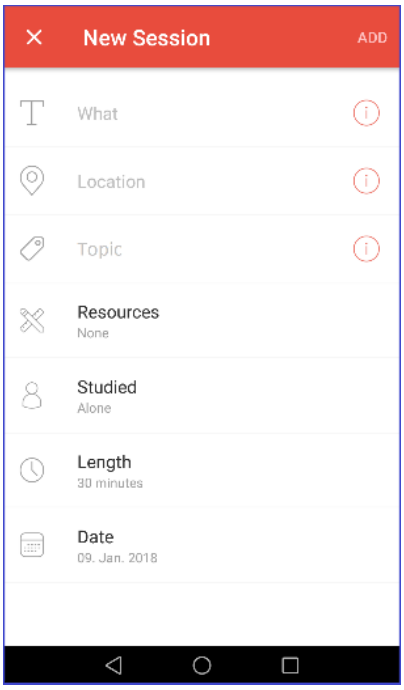
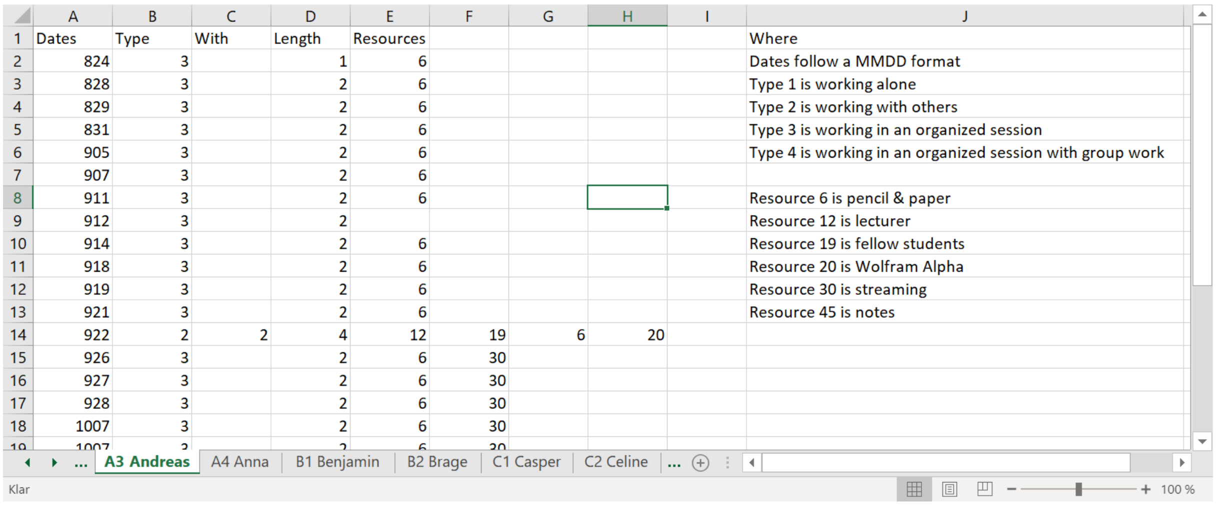


Figure 3.6: The interface of the 'add session' screen of the Studert app, with the seven questions students needed to fill in information on.

The Studert app was designed with seven questions to be answered for each study session. The interface of the app is displayed in figure 3.6. The seven questions were:

1. What. A short description of the type of study session
2. Location. Categorically, where did it take place (i.e. at home, on campus)
3. Topic. What mathematical topic(s) were studied (i.e. integration by parts)
4. Resources. What resources were used (i.e. textbook, calculator, Google)
5. Studied. With the four pre-defined alternatives of "alone", "with others", "in an organized session" and "in an organized session with group work". If the second or fourth option were chosen, how many they studied with was a follow-up question.
6. Length. Predefined options of half an hour, or any whole number of hours up to '8 or more'.
7. Date. Set to the current date by default.

After the changes to the scope of the data collection, the information from the first three question were not considered in further analysis. They were checked only if they could help verify a trend seen in the data from a student. I copied the data into a Microsoft Excel document which included the information from questions four through seven from every study session each student filled in. Included were explanations for which number represented which answer. See figure 3.7 for the structure of the excel document.



	A	B	C	D	E	F	G	H	I	J
1	Dates	Type	With	Length	Resources					Where
2	824	3		1	6					Dates follow a MMDD format
3	828	3		2	6					Type 1 is working alone
4	829	3		2	6					Type 2 is working with others
5	831	3		2	6					Type 3 is working in an organized session
6	905	3		2	6					Type 4 is working in an organized session with group work
7	907	3		2	6					
8	911	3		2	6					Resource 6 is pencil & paper
9	912	3		2						Resource 12 is lecturer
10	914	3		2	6					Resource 19 is fellow students
11	918	3		2	6					Resource 20 is Wolfram Alpha
12	919	3		2	6					Resource 30 is streaming
13	921	3		2	6					Resource 45 is notes
14	922	2	2	4	12	19	6	20		
15	926	3		2	6	30				
16	927	3		2	6	30				
17	928	3		2	6	30				
18	1007	3		2	6	30				

Figure 3.7: The excel document where quantitative data was stored. For each student, every session was represented with information on the date, the length in hours, the resources used and whether they worked alone, with others, in organized sessions alone or in organized sessions with group work. If they worked with others, they also gave information on how many people they worked with. Dates follow an MMDD format, without punctuation between month and date.

3.5.7 Anonymizing the data

In order to keep the institutions and students unidentifiable in the data, I had to go through the list of all answers in the quantitative data and edit any mention of the institution, specific locations, the name of the lecturer or the title of the textbook. For instance, if a student answered the location question with the name of the institution, I would change the answer to "on campus". I would replace the name of the lecturer with "lecturer" and the textbook title with "textbook".

During transcription, I replaced any mention of the university with the codenames in brackets, (i.e. "[University Alpha]"). I replaced the name of the lecturer at University Alpha with "[Andersen]", while the lecturers from Beta and Charlie were replaced with "[Bjørnsen]" and "[Christensen]", respectively. For other staff mentioned by name, I used other Norwegian surnames starting with the same letter as the university's pseudonym. Any reference to the course a student was taking was replaced with "[mathematics X]", "[math X]" or "[MA-X]" depending on whether they used the full Norwegian word for mathematics, an abbreviation or the course code. Any reference to a different mathematics course was replaced in a similar manner, but with a Y, rather than an X. I also changed a place name to "[neighboring town]" and the name of the textbook to "[textbook title]".

3.5.8 Semi-structured interviews with course organizers and collection of contextual data

For each university, I carried out a short interview with the course organizer during the visit for the second round of interviews. Interviews took place in the person's office. Each interview consisted of the same questions that I asked students about the organization of the course. That is, what resources are provided or emphasized; what is the mandatory assessment and examination in the course and which organized sessions are included in a regular week. Unlike the interview with the students, I mentioned all three aspects of interest in the initial question, rather than waiting to see what they answered spontaneously. I was still open to ask follow-up questions. After they answered, I asked them whether there was anything they would like to add about the course.

In the case of "Christensen" from University Charlie the interview took place after the completion of the course. Hence, I could combine the interview with asking for information on the grade distribution in the course and the grades of the the students who had given permissions to use them. For "Andersen" and "Bjørnsen", I communicated with them by e-mail and were sent the information through encrypted documents.

3.6 Analysis tools

Due to the collection of multiple types of data, multiple tools for analysis were needed. In accordance with the idea of mixed methods research being fully mixed, both quantitative and qualitative data should be analyzed both with quantitative and qualitative means. This section concerns how I present the contextual data; a summary for each student; quantitative analysis of the schematic representation of resource systems and most importantly, how I analyzed and present my results using thematic analysis.

3.6.1 Analysis of contextual data on universities

Contextual information on the universities are presented in section 4.1 (page 89). For each university course, I give an approximation of the size of the course. I calculate the grade distribution as percentages. If the course organizer gave me separate numbers for male and female students, or separate numbers for separate types of examination, I use both sets of numbers. For each of the three questions asked to students and staff about the organization of the course, I give a summary of the response of the course organizer. I also give a summary of what aspects of the students' responses are similar or dissimilar to the answer of the course organizer. The summary does not follow rigorous rules, and are meant to boil down a lengthy answer into one that is more to the point. I have included translated transcripts of the interviews in appendixes F-H (starting on page 303), and included notes on my translation process in Appendix D (page 299). I also give my impressions on my rapport with them and the tone of the communication.

3.6.2 Student summaries

Student summaries are presented in section 4.2 (page 98). For each student, I include the contextual information of their grade (if they gave permission) and information on whether they have previous experience with university mathematics. Then I include the translated transcript of the summaries I gave of their first interview during the second interview, as well as their response about its accuracy. I proceed to give summaries of the changes to their resource use (or lack thereof) that they discussed during the second and third interviews and of their answer to the assessment hypothetical. The summaries do not follow specific strategies and are meant to give a holistic idea of the students' resource strategies in a condensed form. They can be considered my interpretation of their answers, but I have made an effort to accurately represent the students' views. I also talk about relation between their interview statements, their mind maps and the data they filled into the Studert app. Student summaries are focused on the resources that students use and their strategies. They do not go into how students discover resources and rarely go into how students make their decisions about what resources to use and how.

3.6.3 Quantitative analysis on schematic representations of resource systems

I conducted a descriptive, analysis of the SRRSs during the spring of 2018. It was conducted early so that I could present a poster about the topic at INDRUM 2018 (Hillesund, 2018). Within the documentational approach, SRRSs are not analyzed on their own, so I looked more generally for methodologies on how to analyze concept maps. I did not find any such tools. Wheeldon and Faubert (2009) conclude that more consideration should be put into what role that concept maps can play in qualitative research. In their experiences, they find that concept maps can be well used in combination with other data collection methods to improve the quality of data collection. For instance, they say that it can be fruitfully used in exploratory studies if the researcher creates new lines of questioning from the maps that participant have created. While I agree, and while that is part of the purpose SRRSs serve in my study, I had to figure out how to interpret the data on my own.

I decided that analysis of each individual student's SRRS should be done after the thematic analysis of the interviews in order to discuss the SRRS in light of the themes, and of the student's own comments on the mind maps they constructed. After all, the students had previously only used mind maps as a way to structure their ideas for their own benefit. The rationale behind the structure of a mind map is not necessarily apparent to anyone but the person who constructed it. At the time, I analyzed the mind maps in a multitude of ways, looking into the structures of the mind maps, the situations and the resources. However, what I think is the most useful to the focus of my project, and what I will include here, is to simply look at every resource and resource category that was brought up in the mind maps and look at how many of the students included it in their mind map. I also take into account differences between the students' initial mind maps and their final mind maps, considering some resources were added and some were removed.

I code each resource or resource category into three categories with two sub-categories each:

- Digital resources
    - Hardware
    - Non-hardware (software, webpages, etc.)
- Material resources
    - Constructed (Self-made)
    - Provided
- Social resources
    - People
    - Events

In the analysis, I will make one table for each category (digital, material and social). Each table will include one row for each university and one for the combined total. There will be one column for each sub-category, and one called others for resources or categories that are too general or too vague to place into one of the other columns, or that are activities tied to certain resources. Then, I will move on to a breakdown section in which I list the number of resources and resource categories that were mentioned in each category and subcategory. I also make a list of how the most commonly mentioned resources fall within the categories and consider which of them are emphasized in any of the courses.

For the various numbers, I keep track of how many students included a resource or resource category in their initial mind map and how many included it in their last mind map. For instance, I write 1/2 if one person included it in their first mind map, but two included it in their last mind map. I simply write 2 if two students included it in all their mind maps. However, I write 2/2 if two students included it in their initial mind map, but one of them removed it, while a third student added it. Sometimes I will put in parentheses how many times the resources were removed and how many times they were added.

When I sum up how many resources were in each of the six subcategories, I use the two values N and M. N denotes the number of resources and resource categories in that subcategory. M counts the number of mentions. That is, M counts each resource X times, where X is the number of students who included it in their mind maps. For both numbers, the above rules for keeping track of both the initial and eventual value applies.

3.6.4 Thematic analysis

Braun and Clarke (2006) argue that some inductive approaches to analyzing qualitative data provide one recipe for all inductive research, while others are more theoretically neutral and can be used differently depending on the theory used. They say that thematic analysis (TA) should be considered an approach of the latter variety. Thematic analysis is concerned with identifying and reporting on patterns in a data set. The approach is open to identifying themes based on the theoretical notions of a theoretical framework and naming the themes based on the terminology of said framework.

How broad a theme should be, is an open question. While it should be seen across the data, Braun and Clarke stresses that there is not a one-to-one correlation between frequency and significance. They argue that following rigid rules is unfruitful and that the researcher needs to use their own judgement. They argue that the focus of your research will affect how you use TA. For instance, that say that TA might be used to reflect on the entire data set, and that such a focus may be a natural choice for an under-researched area. They say that such an approach would lead to a loss of complexity and depth compared to other approaches to TA, that may go more in-depth on a few themes (or even a single one) that are particularly significant to the researcher. Importantly, researchers ought to clarify their focus by considering some significant questions:

- Is your use of thematic analysis inductive or theoretical? That is, do you identify themes based on what is the most accurate summary of the data or do you start with theoretical proposals and look for evidence in the data to back up these proposals. It should be noted that in practice, no inductive approach is fully without bias, so it is rather a question of whether it is more inductive or more theoretical. For inductive TA, the research questions may evolve throughout the process. For theoretical TA, they may be determined in advance and remain fixed.
- Do you identify semantic or latent themes? Braun and Clarke argue that when using TA, researchers usually stick to either patterns in the participants' statements (semantic themes) or try to look beyond the statement for latent meanings and implication (latent themes). The latter

implies a higher level of interpretation and reflection and may be chosen based on the epistemology of your theory.

- What is the epistemology of your paradigm? For obvious reasons, the researcher's views on what knowledge is and the degree to which latent meaning can be derived from the researcher's reflection on someone else's statements, will affect how they identify themes and whether they identify semantic or latent themes.

Braun and Clarke outline a general structure for thematic analysis, which they refer to as the six phases of TA. As they do not advocate rigid rules, the phases of thematic analysis do not contain detailed steps, but rather general phases of the analysis and general principles that the researcher should consider when working out the details for conducting each phase.

1. Familiarizing yourself with your data. Braun and Clarke advocate an active reading-process looking for meanings within the data. They argue that transcribing audio recordings may serve such a purpose quite well.
2. Generating initial codes. Codes are considerably less general than themes. One should go through the entire data set, giving equal attention to every segment. The codes created should be considered ideas that may be the basis for themes. One should code for as many potential themes as possible, even the ones one considers unlikely to be used. The codes should represent all factors in the data, not just the ones you later choose to focus on. It is also important to note that several codes may apply to the same segment.
3. Searching for themes. Looking over the codes and trying to identify themes across the codes, then grouping the extracts from the data into the themes. Themes should constitute patterns of meaning. The phase should result in a structure of themes and sub-themes and collections of extracts. Braun and Clarke say that no themes should be abandoned in this early phase.

4. Reviewing themes. A long process of reflection on the themes and which extracts belong within them, potentially resulting in several instances of re-structuring the system of themes. The goal is *internal homogeneity* and *external heterogeneity* (Braun & Clarke, 2006, p. 91). The extracts within a theme should be similar to each other and dissimilar to the elements of other themes. Still, Braun and Clarke warn not to continue this refinement process infinitely. Every system can be improved, but at one point, one has to settle on a final system.
5. Defining and naming themes. You should be able to clearly state what the theme is and what it is not. You should also be able to say how the subthemes fit within the themes and how the themes relate to the data set as a whole.
6. Writing up. No matter what you are writing up your results for, the task of said writing is "to tell the complicated story of your data in a way which convinces the reader of the merit and validity of your analysis." (Braun & Clarke, 2006, p. 93) It is important to provide evidence through extracts. You need to go through each theme to find a few extracts that support and illustrate the theme particularly well. Those extracts should be incorporated into an analytical narrative. It should also go beyond description to provide arguments related to your research questions.

Braun and Clarke provide a checklist to be used through the course of the six phases to ensure high-quality thematic analysis. The checklist includes 1) Transcriptions are accurate and provide an appropriate level of detail; 2) Each data item has been given equal attention; 3) The coding has been thorough, and themes have not been derived from a few vivid examples; 4) All relevant extracts are collated (in phase 2); 5) Themes have been checked against each other and against the data set; 6) Themes are internally coherent, consistent and distinctive; 7) Data has been analyzed, not just paraphrased; 8) The analysis fits the data and is illustrated by extracts; 9) The analysis tells a well-crafted and consistent story about the data; 10) There is a good balance between analytic narrative and using extracts to back up claims; 11) None of the phases of analysis have been rushed; 12) Theoretical assumptions and type of TA used is clearly stated; 13) Your analysis process clearly adheres to the approach described; 14) The language in your writing is consistent with the epistemology of your theory and 15) You are clear about you the researcher being active in the analysis process, rather than claiming that the themes 'emerged' from the data.

3.6.5 Implementation of thematic analysis

I chose to use the type of thematic analysis Braun and Clarke (2006) mention as a good choice for under-researched areas. I focus on a breadth of issues and sacrifice some depth and complexity in order to do so. I choose the terminology that I 'identify' themes. It should be noted that, in accordance with pragmatism I wish my use of the term to be understood as implying an active process of developing an interpretation that I think other researchers in the field would be able to use fruitfully when studying similar phenomena. It should not be understood as discovering a phenomenon and describing it in an objectively correct fashion. I went into analysis with the intent of identifying themes inductively. However, because my interview foci were derived from the documentational approach, I found that some themes may have been prompted by the focus of the interviews. As a result, I think some of my themes are more inductive and some theoretical. For each theme category in chapter 4, I include a "type of theme" subsection in which I consider the extent to which the theme is inductive. In the same segment, I consider whether it is a latent theme, involving a lot of interpretation, or a semantic theme, mostly concerned with the wording of the statements. In the rest of this subsection, I will detail how I conducted each phase of thematic analysis.

Phase 1: Familiarizing myself with the data

Part of the familiarization process took place when I listened through the first interviews to make summaries for the second interviews. Then, in early 2018, I transcribed all the interviews. Each interview was transcribed in two steps. One quick transcription to write down roughly the right words and one thorough transcription, making sure to get the words correctly and noting down pause lengths, extended words and so on (see transcription scheme in Appendix B, page 294). After transcription, I had some impressions about the content of the data set and topics that maybe, in time, I would transform into themes. To familiarize myself further with the data, I created a document with a section for each topic. Then I read through the entire data set, copying segments into any section within the document that I thought it related to. At that point, the topics were resources; situations; affordances and quality of resources; comments on the course; working with others; checking answers; discovery and appropriations; lectures/lecturer; procedural and conceptual knowledge; views on mathematics and additional information.

Phase 2: Generating initial codes

Initially, I divided the data set into small idea segments. I read through the entire data set, creating rather specific, semantic codes. I quickly decided to create statement codes, condition codes and resource codes. For instance, one of the statement codes was that the student used a certain resource a lot. Rather than create separate codes for using the textbook a lot, using calculator a lot and using GeoGebra a lot, I used the same statement code, but different resource codes. Some of the resource codes were categories of resources. Some statements gave a condition. For instance, let us say that a student said that they used the formula collection a lot when preparing for exams. Then I would code it as a combination of the condition code for ‘preparing for exams’, the statement code for ‘I use [resource(s)] a lot’ and the resource code for ‘formula collection’. In total, I created 21 condition codes, 126 statement codes and 63 resource codes.

After completing the coding scheme, I coded one interview and asked a colleague to conduct an intercoder reliability test with me. I presented him with a condensed version of the scheme (9 condition codes, 24 statement codes, 19 resource codes) and a transcription of the interview. He was given the scheme a few hours before the meeting, to familiarize himself with it and prepare questions about the scheme. Prior to the test, we discussed his questions for clarification. We coded the first half of the interview individually, met up to compare answers, discussed the source of the differences, then coded the second half individually and compared codes again. For the first half, there was a 78% agreement on how we divided the text into idea segments and a 75% agreement on the codes. The agreement on codes rose to 90% after resolving minor differences. For the second half, there was a 95% agreement on dividing the text into idea segments. On the codes, the agreement was 83% before resolving minor differences and 95% afterwards. I considered this agreement to be satisfactory and went on to code the rest of the data set.

Phase 3: Searching for themes

After I had coded all the themes, I created a document to make notes as I actively read through the coded statements. The codes were divided into groups. For instance, one group included codes on the extent to which various resources were used and one group included general opinions on mathematics and on learning. For each group, I read through every excerpt I had coded within it, condensing statements to short summaries, reading over the summaries and writing down my impressions in a subsection called 'possible themes'. After this process, I compared the possible themes from the various groups to look for similar impressions across groups. Through reflection on these impressions, as well as previous impressions from the familiarization phase, I created an initial system of themes. Compiling the excerpts for each theme was more closely tied to the next phase.

Phase 4: Reviewing themes

After creating the initial system of themes, I was unhappy with the short length of the excerpts. I read through the data set again, coding potentially longer sections within each themes. Additionally, I used this process to reflect on how well my initial system of themes described the data, making multiple changes along the way. Because I found it easier to reflect on themes when working on a task, I proceeded to create the following task for further reflection. Using the excerpt scheme (long form) detailed in Appendix E (page 301), I copied the excerpts over into a Microsoft Word document, and noted down the context of the excerpt within the data, what part of which interview it was from and to what degree I thought my questions prompted the statement. I reflected on how well each excerpt fit within each theme, as well as the quality of the system as a whole. Part of this work is reflected in the structure of the excerpts in appendix I (page 320). I was not quite faithful to thematic analysis, because I decided that some excerpts may relate to multiple themes. I found examples of the same statement highlighting multiple phenomena and did not find it useful to restrict myself to including such statements within a single theme.

Phase 5: Naming and defining

Trying to give clear names and definitions to each theme led to realizations that some themes were hard to define because they were not internally coherent. Thus, I made some changes to the system in this phase as well. I created a document for this phase, where for each theme I included a name and a definition, as well as how many excerpts from each student related to the theme, to what degree I considered the theme inductive and how the theme might relate to the documentational approach. I also included a few excerpts for each theme and translated them from Norwegian to English.

Phase 6: Writing up

I divide my themes into theme categories. Several of the themes within a category have subthemes. Often, the themes are more general than the subthemes. For instance, if the theme is that students have resources that they use for introduction, the subtheme might say something about what resources are often used for introduction. I also include what I refer to as results. These are not regarded as themes or subthemes because they are not sufficiently represented in the data, but they are included because I still find them intriguing and see them as potential foci for future research.

In section 4.4 of this thesis (page 126), I include an overview to discuss relationships between theme categories. For each theme category, I include a table with the number of interview segments that each theme, subtheme and result was based on (developed in phase 5). I include a section about the category, for instance linking it to the documentational approach. The description of each theme includes an analytical narrative, where I refer to excerpts and potentially schematic representations of resource systems and data from the Studert app to support my argumentation. Each theme is followed by its subthemes. At the end of the section for each theme category, I include a 'type of themes' subsection, where I consider whether the various themes and subthemes within the section are latent or semantic and whether my identification of them was truly inductive or a result of biases in the interview questions.

During analysis, I had a separate phase where I linked SRRS data and app data to the themes. In this phase I considered what sort of data could support or contradict each theme (either by their presence or their absence). The degree varied. For instance, app data was quite relevant to determine how students used resources differently during exam preparation, but did not have the potential to say much about how difficulty affected their use of resources. In the thesis I incorporated these results into the theme descriptions.

Chapter 4: Results

This sections covers information gathered on the mathematics courses that the students within the project attended, here called contextual information, and on the students' use of resources, either specific to each students or across the sample. The student summaries detail each students' use of resources. In addition, I include statistics on the extent to which various resources were included in the schematic representations of resource systems (SRRSs). Lastly, I cover the themes identified based on the interviews, SRRSs and app data. I found that the majority of the themes fit within one of the theme categories class of situations; schemes of utilization; didactical resource purposes; evolution of documents; resource decisions; resource discovery and quality criteria.

4.1 Contextual information

This section contains information on the approximate size of the courses; the grade distribution within the courses and summaries on what students and course organizers said were the resources emphasized within the courses; the organized sessions within the courses and the mandatory tests and examinations. For more information, see the 'semi-structured interviews with course organizers and collection of contextual data' subsections in the methodology chapter (starting on page 78). For more information on resources that are mentioned, see the list of resources in Appendix J (page 401).

Before I address each individual university, I will address some common factors. At each university, the students were engaging in an introductory calculus course, and each university is in Norway. The focus within introductory calculus courses in the Norwegian university context is similar to corresponding courses in the American university context, and in each of the three courses an American textbook is used. Tallman, Carlson, Bressoud and Pearson (2016) investigated the exams of all introductory calculus courses in the United States, including mathematics students and students in other STEM programs requiring calculus. They found that on average, 85.2% of the exam questions involved either recalling a mathematical fact or following a rehearsed procedure to produce an answer. To my knowledge, no studies have analyzed exam questions for introductory calculus courses in the same way in Norway. However, it is my experience that proofs are not emphasized in Norwegian introductory calculus courses. Related to the three courses studied here, proof was neither mentioned by students nor course organizers. However, Bjørnsen did mention that the exam questions were largely based on understanding, possibly suggesting a somewhat different focus at University Beta.

4.1.1 University Alpha

Approximate course size: 150 students

Grade distribution

The grade distribution for the course at University Alpha is displayed in table 4.1. The grade distribution was negatively skewed.

	A	**B**	**C**	**D**	**E**	**F**
Written exam	6%	6%	14%	22%	27%	25%

Table 4.1: The grade distribution from the written exams on the course at University Alpha.

Given a model where A=5, B=4, C=3, D=2, E=1 and F=0, the average grade at written exam in the course at University Alpha was 1.67 (D-).

Further information about examination

Numbers represent the people who completed the exam. No numbers were provided on how many walked out from the exams or did not show up to exams.

Organization of the course

Table 4.2 shows my summary of what Andersen (course organizer and only lecturer at the University Alpha course) said about the organization of the mathematics course. It also shows my summary of how the students' answers about the organization of the course compared to or contrasted Andersen's description. The translated and the original transcription of the interview with Andersen is included in Appendix F (page 303).

Question	Andersen	Students
What resources were provided and emphasized in the course?	Textbook (written in English). Lecturer-made notes from the lectures are published. Students may not use the textbook much and use the lecturer's notes instead.	Adrian mentions an emphasis on recommended exercises that are solvable with pencil and paper. Reveals that Canvas is the platform where the lecturer publishes information. Anna says that the textbook is not really needed except for the exercises within it.
What forms of examination and mandatory assignments were in the course?	Students need to pass two out of three mandatory assignments. Written exam at the end.	Same as the lecturer. Anna reveals that they usually get the assignments two weeks prior to deadline. The students also mention being allowed to bring a self-written A4 sheet of paper for the exams (which I will refer to as an 'exam sheet').
What organized sessions for students were included in a regular week?	Three two-hour lectures, that are also live-streamed. Slow progression and high focus on exercises because it is the students' first year. A projector is used to display notes that the lecturer writes in real time. 'Homework help' sessions where older students help the students of the course with recommended exercises.	Adrian mentions that the videos of the lectures are streamed on Mediasite. Says that the first lecture is focused on the new content, with more examples of exercises in the second lecture, while the third varies between repetition, exercises and new content. Adrian and Anna mentioned that the lecturer often solves some of the recommended exercises at the start of lectures.

Anything else you would like to mention about the course?		Andreas mentions preferring to take notes on his own rather than reading the lecturer's published notes.

Table 4.2: The course organizer's and the students' answers to questions about the organization of the course at University Alpha.

Impression of rapport with course organizer during the interview

I wrote in my field notes that Anderson sounded rather defensive, particularly at the start of the interview. He sounded like he talked to someone who was there to evaluate him. He seemed to be worried about being judged, rather than excited about discussing the course. In Norway, politicians and teacher educators tend to idealize innovation and variety in teaching. This may be why Andersen was not eager to discuss a course that he himself described as "traditional". It should also be noted that Anderson is not the one I initially approached about participating in the study. My contact person, asked him to because she herself did not teach any courses that semester. It is possible that Andersen himself was not enthusiastic about participating in the project, but felt obliged to accept.

4.1.2 University Beta

Approximate course size: 25 students

Grade distribution

The grade distribution for the examinations at University Beta is displayed in table 4.3. The grade distribution for the work folder evaluation was quite positively skewed, while the grade distribution for the written exam is closer to a normal distribution.

	A	**B**	**C**	**D**	**E**	**F**
Written exam	9%	23%	18%	23%	27%	0%
Work folder evaluation	61%	30%	4%	4%	0%	0%

Table 4.3: The grade distribution from the written exams and work folder evaluations from the course at University Beta.

Given a model where A=5, B=4, C=3, D=2, E=1 and F=0, the average grades at the written exam and work folder evaluations in the course at University Beta were 2.64 (C-) and 4.49 (B+) respectively.

Further information about examination

For the final grade, the written exam and work folder evaluation were weighted 60% and 40%, respectively. The written exam numbers represent the people who completed the exam. One student did not show up to the written exam.

Organization of the course

Table 4.4 shows my summary of what Bjørnsen (course organizer and only lecturer at the University Beta course) said about the organization of the mathematics course. It also shows my summary of how the students' answers about the organization of the course compared to or contrasted Bjørnsen's description. The translated and the original transcription of the interview with Bjørnsen is included in Appendix G (page 306).

Question	**Bjørnsen**	**Students**
What resources were provided and emphasized in the course?	Canvas, with relevant information for each week. Links to exercises, video lectures and digital textbook. There is also a physical version of the textbook. Exercises to solve in MyMathLabs. Several links to resources that are not highly emphasized in the course, including SimReal, Mathcenter and the Sinus website (which includes videos on the topics). Students are given	Benjamin says that there are enough videos to not attend lectures, but that attending lectures is very beneficial, particularly when it comes to tips for the exams. He also mentions that they use Maxima for a project. Brage says Canvas is a bit unnecessary and that the lecturer has in a sense replaced Canvas with MyMathLabs.

	a lot of freedom, but the impression is that most of them focus on MyMathLabs exercises.	
What forms of examination and mandatory assignments were in the course?	Written exam as well as three assignments that count towards a folder evaluation.	Brage mentions that the assignments count towards 40% of the grade, and that they do get a second attempt to pass each assignment.
What organized sessions for students were included in a regular week?	Two-hour long lecture focused on 'the main points' and doing examples. Makes it clear to students what they need to remember. Sessions to work on group tasks, but attendance is not mandatory.	Benjamin reports that the second session of the week, which he calls *øvingstime* (literal translation practice class or exercise class) is a bit early and often tempting to skip. He also mentions that the exam tasks are 'simple' and tied to 'understanding'. He says no digital resources are available during the exam.
Anything else you would like to mention about the course?	For the future, will keep the degree of freedom and make sure it is still possible for students to work whenever and wherever they want through web-based resources, but will probably still arrange lectures that he recommends that the students attend.	Benjamin reports faster progression in the course than the course he took during his first year.

Table 4.4: The course organizer's and the students' answers to questions about the organization of the course at University Beta.

Impression of rapport with course organizer during the interview

Bjørnsen seemed excited to talk about the course. The communication was similar to how I assume he would talk to a colleague, sharing his thoughts on and experiences from designing the course. Also discusses how he organized past versions of the course and how he may organize future versions.

4.1.3 University Charlie

Approximate course size: 2000 students

Grade distribution

The grade distribution at University Charlie is displayed in table 4.5. The grade distribution for male students was positively skewed, and the grade distribution for female students was slightly positively skewed. The grade factors in both an exam and a work folder.

	A	B	C	D	E	F
Men	23%	30%	23%	12%	5%	7%
Women	15%	22%	29%	21%	4%	9%

Table 4.5: The grade distribution for the course at University Charlie, differentiated based on gender.

Given a model where A=5, B=4, C=3, D=2, E=1 and F=0, the average grade in the course at University Charlie was 3.33 (C+) for male students and 2.96 (C) for female students.

Further information about examination

Numbers represent the people who completed the exam. The number of people who walked out of the exams was 1% for each gender, while 8% of male and 5% of female students did not attend the exam. Note that students needed to pass a certain number of tests and mandatory assignments to be allowed to attend the exam.

Organization of the course

Table 4.6 shows my summary of what Christensen (course organizer at the University Charlie course) said about the organization of the mathematics course. It also shows my summary of how the students' answers about the organization of the course compared to or contrasted Christensen's description. The translated and the original transcription of the interview with Christensen is included in Appendix H (page 313).

Question	**Christensen**	**Students**
What resources were provided and emphasized in the course?	The course page with theory pages and example of solved exercises; video lectures; recommended exercises; 'math lab' (student support centers) and a textbook in English. The impression is that the textbook is not used much and that some students use the digital resources 'eagerly' while others are barely aware of them.	Casper reveals that the math lab is open eight hours every weekday. He says the textbook is the main resource that is emphasized, and that he is not very fond of it. Celine says that recommended exercises are emphasized the most, and also mentions the website and theory pages. Casper says they have no learning platform while Celine says they have a university-specific platform for assignments, while Christian thinks they have something, but is not sure what and do not think it is used much. Christian mentions that while it is not emphasized, one of the lecturers have a YouTube page with videos about the mathematical topics. While not mentioned when discussing the course, it was mentioned elsewhere that a compendium was provided.

What forms of examination and mandatory assignments were in the course?	Students need to pass six out of twelve Maple TA tests. Also gives bonus points in a folder evaluation based on written assignments. See further information in the notes below.	Casper expresses frustration with Maple TA's automatic assessment features and the false negatives caused by syntax issues. Celine reveals that students need to pass two out of four written assignments, but it is beneficial to pass all of them.
What organized sessions for students were included in a regular week?	Starts with an 'overview lecture' giving an overview of that week's topic. There is an 'interactive lecture' partially based on the flipped classroom principles. The intent is to identify and help students overcome potential misconceptions and other difficulties. There is also a 'plenary' session, showing solutions of that week's recommended exercises.	Casper considers the overview lecture to have too much theory at once and would like the lecturer to alternate more between theory and examples. Celine reveals that lectures are filmed. Christian reveals that each organized session is 2x45minutes long.
Anything else you would like to mention about the course?	Describes it as a continuation of R2 (the highest level mathematics course in Norwegian secondary school). Says that the structure of the course is a result of the institute participating in an innovative education project.	

Table 4.6: The course organizer's and the students' answers to questions about the organization of the course at University Charlie.

Impression of rapport with course organizer during the interview

Christensen appeared quite proud of the course. The communication was quite formal and similar to how I assume he would talk to a journalist interviewing him about the course. He made an effort to relate the structure of the course to a project for educational innovation. Interestingly, Christensen did not mention the textbook until I specifically asked whether they had one.

Notes

I did not ask Christensen about examination because I thought he had answered it spontaneously. I failed to realize that he had not mentioned the written exam. When Casper asked whether his opinions on the structure of the course were part of my question, I answered yes even though they initially were not.

4.2 Student summaries

In this section, I give a summary of the resource use for each student. First, I present excerpts related to summaries I gave to students during the second interview with them, based on the first interview, including their responses about the accuracy. Then, I go on to summarize what they communicated about their use of resources in the second and third interview, as well as the data from their use of the Studert app and from the mind maps they constructed.

4.2.1 Adrian (A1)

Grade: A

Former university experience: One year at University Charlie before he switched to University Alpha.

I presented Adrian with the following summaries about his use of resources during the second interview:

I: First I have written that (1.0) er, when there is a new topic, then (1.0) you assess whether you need more resources for the problem or the most basic. That you (0.5) prefer to do things on paper if possible, for instance rather than polynomial functions on the calculator. Ehm… (0.5) that you have several resources linked to checking answers, for instance graph tools in GeoGebra, talking with fellow students and Wolfram Alpha, but you have not used the latter that much. And… you said you get a lot of use from Rottmann's formula collection.

A1: Yes. That is correct. (Adrian 2,1)

I: Ehm. (3.0) Let me see. (1.5) So, when it comes to (0.5) doing things your own way, you last mentioned (1.0) that you had (0.5) discovered 3D-graphics in GeoGebra on your own. Ehm, is there more you would add (1.0) from lately.

A1: (4.0) Well, no, not really, have not done very much new since the last time, so… (1.0) Have nothing of it in math, really. (Adrian 2,4)

I: I see. Ehm (1.0) about (0.5) working with others you said last time that you are a group who (0.5) potentially sit and work and that it varies from two to five how many who sit there. Is it mostly the same, or…?

A1: Well, have been a bit busy lately, with work and such in [neighboring town], so it has not been (0.5) as often as I would wish but I think that (0.5) the rest of the group are to take on a math assignment later today, actually, but [inaudible] to [neighboring town], because I have both work there and a hairdresser appointment. (Adrian 2,5)

In retrospect, I should have also mentioned in my summary, that what he defined as easily available resources were the textbook and his calculator, while he mentioned the internet and CAS tools as other resources he could potentially use.

Working slightly less with others was the only change Adrian mentioned during the second interview, and he made no changes to his mind map. He also mentioned that compared to his year at University Charlie, he used the calculator more. During the third interview, he added formula collection to the mind map and reported that he used formula collection more. He said the main difference since the second interview was that he worked on previous exam problems rather than regular exercises. He also mentioned not having used GeoGebra much, and not having worked on mathematics at all when preparing for other exams. He said the changes were due to the exam period and said that when he worked on previous exam sets, he would not use resources that would be considered cheating on the actual exam. While Adrian had not written his exam sheet yet he revealed his plan to look at the previous exam sets from the last five years to consider what is important and compare with a formula collection to see what information is unnecessary to write because it is covered there. Related to social resources, he says that he has not worked much with others in the time when he did not work much on mathematics at all, but will work more both alone and with others leading up to the exams.

During questions about his experiences participating in the project, he mentions something new, which he may not have considered a resource. Namely, that he uses a ring folder to sort his notes from different courses, so he does not have to have a notebook for every course.

Figure 4.1 shows the schematic representation of Adrian's resource system based on the final version of his mind map. While in the interviews he merely mentioned using the textbook, in his mind map he wrote that he used it to find exercises, to look up formulas and for repetition. The other purpose items communicates that he used fellow students to check answers and for support; that he used Google to look up formulas and rules, that GeoGebra was mostly for geometry; that the calculator was mostly for calculation and that he may use either excel or the calculator for mathematics that involved tables.

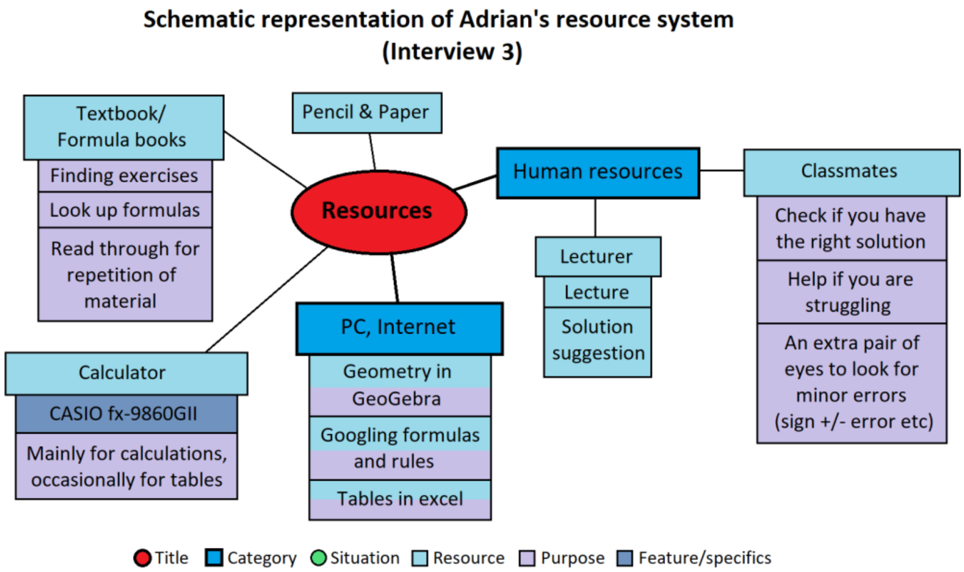


Figure 4.1: The SRRS based on the final version of Adrian's mind map. It contains two resource category items, eleven resources, ten resource purposes and one item on specifics.

The app data from Adrian showed him attending 30 lectures, working with fellow students twice (around the time of mandatory assessments) and working alone twice. Beyond the implied resources lectures and fellow students, he only filled in the same three resources (pencil and paper, textbook, and calculator) during the sessions. GeoGebra, Google and Excel were not represented in the app data, despite being represented in the SRRSs. It should be noted that Adrian did not fill in data after the third interview (when he reported that he would work a lot more on mathematics both alone and with others). One possibility is that he did not fill in every session accurately. It is also possible that the discrepancy between interviews and app data means that some of the resource strategies Adrian mentioned were strategies developed during his year at University Charlie, that he never ended up using at University Alpha or only used during the first two weeks before he was recruited for the project. He did mention that he did not find the course very challenging (perhaps due to taking a similar course at University Charlie), and he did get an A in the course, which may support the latter interpretation. Based on the data, he worked six hours on mathematics during a regular week.

4.2.2 Amalie (A2)

Grade: Not available (Amalie did not give permission to use her grade when she signed up for participation)
Former university experience: None.

The second interview with Amalie was cancelled, so I did not give her a summary in person. However, I think her answer to the most open question during the first interview was rather concise and covered most of her resource use:

A2 Like, the textbook to (1.5) find… (1.0) like (0.5) the curriculum we are covering and how I am to do the exercises and such. Internet too to find out (0.5) how I solve exercises as well, for inst… - instance for the, and… pretty much like the book. Others in class to cooperate (0.5) on the exercises. Ehm… then I get help from home if I need help on how to solve them, because… (1.5) Er… (0.5) *I don't know*, Mom has studied math herself, right, so (0.5) I get a lot of help there, right. And then I learn through doing exercises, that is sitting and doing more exercises and find out what – the stuff I do wrong and (1.0) how I should do them. Also, I look at my old math books. Now that we get, like, exercises that we have had before and such and… how to calculate them. And then the teacher, right. (Amalie 1,2)

She also expressed during the first interview that she thought mathematics was mostly about exercises. When asked about resources she made her own, she discussed the way she used her old math books for familiar topics. Her description revealed that she meant her notebooks from upper secondary school. When asked about social resources, she said she preferred to work with others because she liked discussion and felt she learned more. When she wondered about something, she occasionally asked the lecturer either in a lecture or otherwise. When she worked alone, her main resources were her old math books and her mother, while when she worked with others, they used the textbook and asked the lecturer.

During the third interview, Amalie said she had started using previous exam sets in addition to the exercises in the book. She said she had taken a break from working on mathematics when she had exams in other courses. Amalie made no changes to her mind map. It simply included the resources she used (see figure 4.2). Amalie did not fill in any information using the Studert app.

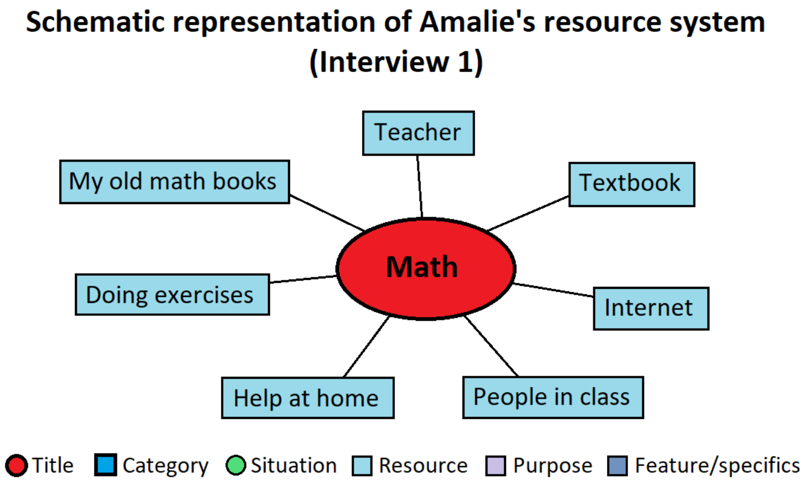


Figure 4.2: The SRRS based on the final version of Amalie's mind map. It contains the seven resources 'teacher', 'textbook', 'internet', 'people in class', 'help at home', 'doing exercises', and 'my old math books'.

4.2.3 Andreas (A3)

Grade: D

Former university experience: Preparatory mathematics course at University Alpha.

I presented Andreas with the following summaries about his use of resources during the second interview:

I Ehm, you said you go to all the lectures you are able to, ehm, use pen and paper to learn formulas and notation. If you need visual representation, you go to GeoGebra, Wolfram Alpha or calculator. For pure calculation, you mostly use old notes. You ask questions to teacher and fellow students if you are stuck on something, and you have not done that many recommended exercises.

A3 Correct. (Andreas 2,1)

I I see. (3.5) Ehm (1.5) last time you said when it comes to resources that you have made your own then (0.5) primarily that when you explain to other students you use a lot of metaphors and practical examples. Do you have more to add now?

A3 (7.0) No, I stand by that it – I do it the same way, I do. (Andreas 2,7)

I Okey. Ehm… (1.0) You also said that you try to find at least one person to do exercises with, that you (0.5) do not like to learn things on your own. Ehm… often work with 2-3 others, and (1.0) er (0.5) there have not been much group work this year, but I did not catch if you meant group work organized by…

A3 No, it is – then I mean (1.5) that we on our own find groups, that we find either friends or classmates to work with.

I I see. How does that fit, like, as of now?

A3 It still fits as of now, it is… (0.5) hard to find the time, and it is hard to find (0.5) others who have found time exactly when I have found time for mathematics. So if I work on exercises, I probably work alone. (Andreas 2,9)

Figure 4.3 shows the SRRS based on Andreas mind map from the first interview. It gives a lot of information on the purposes he used resources for, including learning notations and formulas through muscle memory; learning from teaching to others and using resources for what he called ‘getting unstuck’, ‘academic progression’ and ‘academic depth’. I interpret ‘getting unstuck’ as finding a way to solve a task he had difficulty with and spent a lot of time on. I interpret academic progression as learning new mathematical content and academic depth as deepening his understanding of the content.

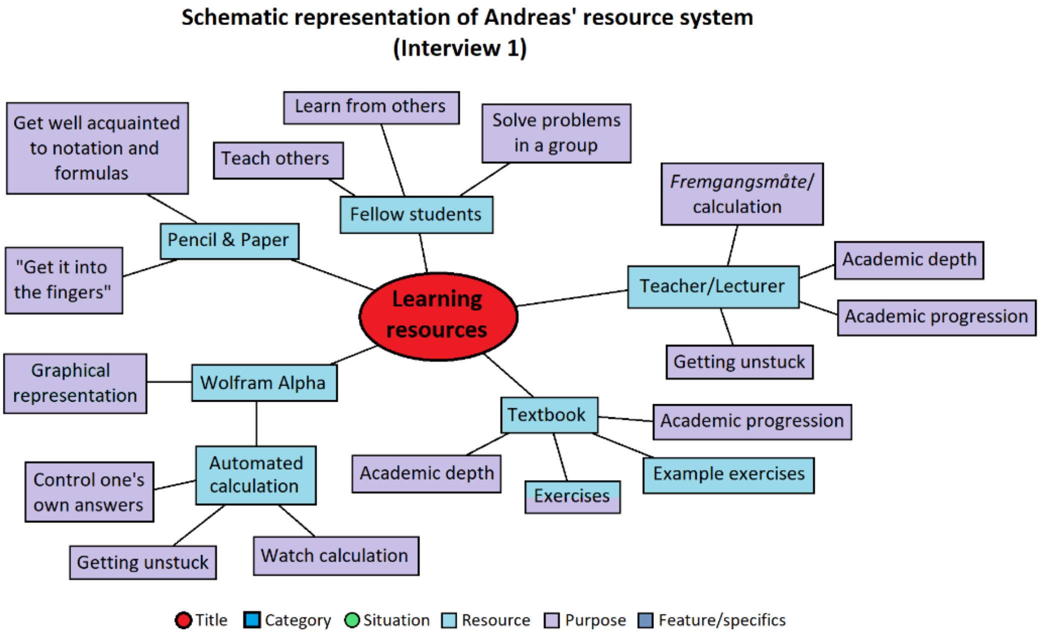


Figure 4.3: The SRRS based on the final version of Andreas' mind map. It contains eight resources and 13 purposes (three of which were mentioned twice). During the second interview he removed three of the purpose items.

During the second interview, Andreas reported using the streams of the lectures and otherwise not using digital resources very much, calling them too cumbersome for the exercises they worked on currently, which involved integrals. He also felt less need for digital resources because he did not get stuck very often. When updating his mind map, he removed graphical representation as a purpose tied to Wolfram Alpha; getting unstuck as a purpose tied to automated calculation and academic progression as a purpose tied to the textbook. When asked whether he thought they were long-term changes, he said that the change regarding the textbook may be temporary, but thought he would use digital resources less the harder the topics got.

Andreas made no changes to his mind map during the third interview. He said that he used the same resources, but put more "weight" on some than previously. For instance, he relied more on social resources than previously. One reason was that he had not worked much on mathematics for a while and thought other students had "had more progression" than him. He stated again that he has used the streaming a lot, saying he likes the chance to control the tempo. He said that he still did not use the textbook for progression, but that it still could change and that he thought it was important to have a textbook. He said one could ‘unintentionally’ learn from a textbook by flipping through it and suddenly noticing something.

The data that Andreas filled into the app showed that he initially just used lectures and pencil and paper for a month. Then there was one four-hour session where he worked with others and also used Wolfram Alpha and the lecturer as resources. Afterwards, the rest of the sessions he used the lecture streams and pencil and paper, besides a single session when he worked with others and used ‘notes’ as a resource. He only filled in one four-hour session from his exam preparation (using lecture streams and pencil and paper. Usually he worked approximately six hours a week on mathematics.

4.2.4 Anna (A4)

Grade: B
Former university experience: None.

I presented Anna with the following summaries about her use of resources during the second interview:

I So, this time I… (0.5) have tried to make summaries of things you said last time, so (0.5) part of the interview is to (1.0) say if there is something you want to correct, add or something that has changed since last time. So (0.5) I have written that (2.0) you take notes during lectures and afterwards go through the notes and mark what is important. That you refresh often, both when you work on exercises and often during the weekends. That you t… – in – that you also use the textbook, calculator, writing equipment, working with others on exercises and potentially search online for explanations. Of digital resources you have so far only used calculator, but you also have GeoGebra available. So (0.5) is there anything you want to correct or add to (0.5) that?

A4 No, it sounds good [laughs]. (Anna 2,1)

I Ehm (2.0) Then I wrote from last time that (2.0) there were no resources you felt you had made your own, has that (0.5) changed at all (1.0) since then?

A4 No. [laughs] (Anna 2,4)

I Ehm… I see, so speaking of, working with others, last time you said that you (1.0) often work with – that you worked with two to three (0.5) fellow students when you worked with someone and that it was often one to two times a week that you worked with others. So (1.5) You said it had gone up a bit, what – how much do you work with others now?

A4 Er… (2.5) three to four times, maybe. (Anna 2,5)

During the second interview, Anna mentioned the mathematical content being more difficult and complicated, and said that was the reason why she worked more with others. She also mentions that it had been a couple of years since she finished upper secondary, so while a lot of the content was similar to the R2 course at upper secondary, she did not remember it that well.

During the third interview, Anna said that she had not worked on mathematics when preparing for other exams, but had recently started again. She updated her mind map by including the exam sheet and mentioned it as a resource she had made her own. She made it by comparing lecture notes and the formula collection to judge which points were important while not being available in the formula collection. She said that she had used formula collection to an increasing extent because it was allowed at exams. She also said she planned to use formula collection more throughout the next semester, to be more familiar with it.

Figure 4.4 shows the SRRS based on Anna's mind map from the final interview. She included many of her strategies in the mind map, often referring to activities (which I still coded as resources), such as reading through the textbook and doing exercises. Her mind map showed that she emphasized repetition, comparing her work with other students, reading and doing exercises. She also used the solution suggestion in the textbook sparingly.

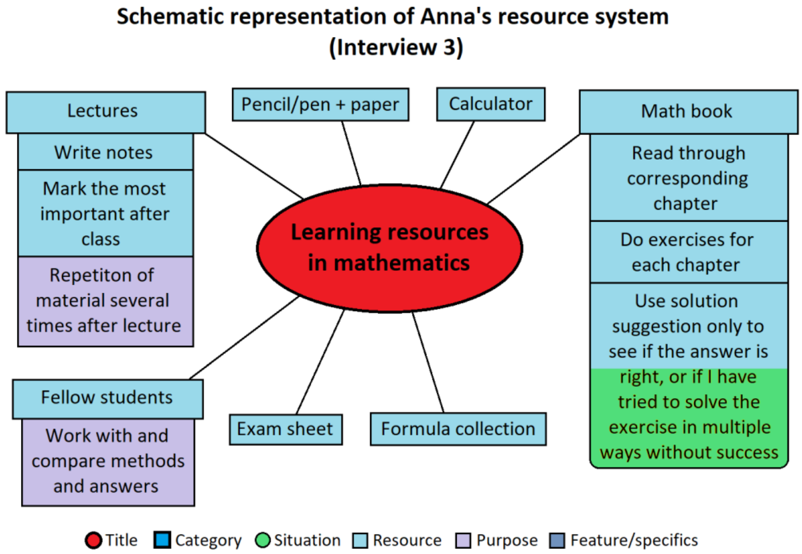


Figure 4.4: The SRRS based on the final version of Anna's mind map. She phrases several resources as activities and was able to communicate several of her strategies through the mind map, such as marking the most important notes, using repetition and only checking the solutions to see if the answer is correct.

Anna stopped filling information into the app after four weeks. During each of these four weeks she attended all three lectures and worked alone and with others for at least one extra session each. She worked on mathematics for ten hours a week. Every session included calculator and pencil and paper, 15 out of 23 involved the textbook and one involved using the internet.

4.2.5 Benjamin (B1)

Written exam grade: A
Folder evaluation grade: A
Former university experience: One year at University Beta

I presented Benjamin with the following summaries about his use of resources during the second interview:

I So, (1.0) this time I have tried to make some summaries of what you said last time, and then (1.0) I would like you to say if there is something that (0.5) you would add, either (0.5) ehm (0.5) because it is new or because it (1.0) to improve the summary, right. So (1.0) er, since last time, I got that you (1.0) use the video lectures, textbook as a supplement and MyMathLabs for exercises. That when you have a lot of time you prepare before lectures. Use video… – that – use the video lectures quite a bit, and… with less time you use the textbook and lectures. And on occassion you use Wolfram Alpha, google things and use YouTube videos.

B1 Yes. (Benjamin 2,1)

I Ehm (1.0) when it comes to resources that you felt you had made your own last time, you mentioned last time that you first and foremost had (0.5) strategies for how you used the videos, like playing them fast, skipping, taking notes and rewatching. Ehm (1.0) is there more you would like to add to…?

B1 Ehm… No, not really. (Benjamin 2,5)

I Ehm (4.0) when it comes to (0.5) like, working with others, you… (1.5) said that you feel like you learn a lot by working with people at the same level as you, but that you (1.0) mostly work alone, primarily because (0.5) ehm (0.5) spare time filled with training. Ehm (0.5) how correct is that… (1.0) as of now?

B1 Er, it is quite similar there, it is of course better to work with others than – when one solves exercises and such. Er, for me it often comes down to getting to explain to others (1.5) and it makes it so I get a better understanding of things (1.5) Ehm… (0.5) so what I usually – that is usually the best way to work for me personally, ehm… (1.0) but it takes a long time to go through exercises that way. Er, because… if one has to explain a lot or need a lot of explaining oneself, or stuff like that, then it is, like – an exercise takes a very long time and (1.5) I do not have that much time right now, so… then it is a lot (1.0) a lot of the same, but it is not just training, it is a lot – I am part of a union, I am chosen representative and so on, so (2.0) there is a lot to do. (Benjamin 2,6)

During the second interview, Benjamin reported using the textbook more than videos, said that he had prioritized other courses and tried to work efficiently in mathematics. He said that at the moment, he mostly focused on understanding the topics, and not working on exercises, but that he would work more on exercises leading up to exams. To his mind map, he added a category for internet and included videos and Wolfram Alpha in it. During the third interview, he added a category for interactive, and simulations as a resource, as well as the purpose chance to ask questions. Figure 4.5 shows the SRRS based on the final version of Benjamin's mind map. Related to simulations, he talked about using sliders in GeoGebra to look at how different values affect something. He said that the chance to ask questions is important to him and he finds it useful to ask a lot of "stupid questions". He reported that all the changes to the mind map were just issues that he did not think about the last time, rather than changes to his use of resources.

During the third interview, Benjamin said that he had used MyMathLabs more than previously because some exercises tied to an assignment made him aware that he needed more practice in order to solve exercises quicker. I asked him to elaborate on his use of the word understanding, and what resources he used for it. He mentioned the introductory video lectures for a topic focusing on the question 'what is this?' and putting the topic in perspective. He also mentioned gaining understanding from 'practical examples' in the textbook that show what the topic is used for.

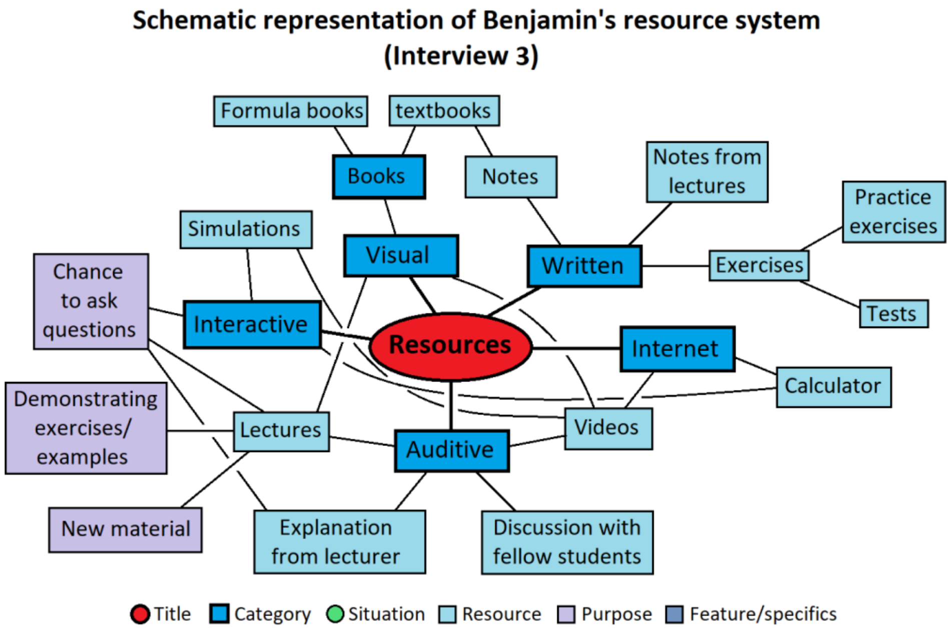


Figure 4.5: The SRRS based on the final version of Benjamin's mind map. It contains six categories, 13 resources and three purposes, with several resources being tied to multiple categories and the chance to ask questions purpose being tied to two resources and a category.

As figure 4.5 shows, Benjamin included many resources in his mind maps and tied them to the resource categories books, visual, written, internet, auditive, and interactive. For most of them, he did not include purposes, but for lectures, he included the three purposes of chance to ask questions; demonstrating exercises/examples and new material. Chance to ask questions was also a purpose for explanations from lecturer and the interactive category.

The data that Benjamin filled into the Studert app, showed him working regularly during the first month of participation. During the second month, he only filled in a single session. During the last month, he took a break for two weeks (possibly for other exams), but the sessions he filled in prior and after the break were longer and involved more resources than the sessions during the first month. The sessions also involved MyMathLabs, calculator, pencil and paper, videos and notes, while the sessions during the first month involved pencil and paper, videos and the textbook. Table 4.7 shows some of the differences between the first and the last month. The data seems to show a significant shift towards doing more exercises and working more during preparations for exams.

Comparison between the first and the last month that Benjamin filled information about study sessions into the Studert app		
Statistic	**First month**	**Last month**
Number of sessions	10	5
Total time spent (in hours)	18.5	17
Average session length (in hours)	1.85	3.4
Average number of resources used per session	2.7	3.8
Number of sessions using MyMathLabs	0	4
Number of sessions using calculator	0	3

Table 4.7: Benjamin's use of resources based on information from the Studert app. During the last month that he filled in information, Benjamin had longer study sessions, using more resources and using more exercise-centered resources than during the first month.

4.2.6 Brage (B2)

Written exam grade: B
Folder evaluation grade: A
Former university experience: One year at University Beta

I presented Brage with the following summaries about his use of resources during the second interview:

I So first, ehm (1.0) that MyMathLabs is what you use the most and that you value the step by step explanations. That… you use video lectures and go to the book if you are not quite satisfied with the explanations. Occasionally you Google something or go to YouTube to get multiple perspectives on things. After the videos you go (1.0) to work on exercises. If you run into problems, you look at s… – at examples in MyMathLabs and potentially check the textbook.

B2 Mm, yes it fits very well with (1.0) how I use… the tools. (2.0) Mm (0.5) so it is still the same… (0.5) that I do. Like, lately – for the last week we have had a Maxima project. Then I have used the textbook (1.0) the most (0.5) to look at the formulas I needed to use and such. (Brage 2,1)

I Ehm, last time you said that there was no resource that you felt like you had made your own. Would you still say that?

B2 Yes… (1.0) I use them, I guess, how one is intended to use them, in a way, so… (1.0) I do not think I would say that I made them my own, really. (Brage 2,6)

I Ehm, so about (0.5) lecturer and working with others you (0.5) said that you (1.0) like to contemplate things on your own first, before you potentially ask the lecturer. And you work with others four to six hours a week and prefer to work with (0.5) two to three others. Would you say that that (0.5) fits well?

B2 Yes. I feel like if I think – if I have a problem (0.5) and try to work on it on my own first, then I sort of learn the most, because then I have to, like, think how to solve it, rather than to ask 'how does one solve this' right away. Er… and… (0.5) About working with others, I work – I would say I work more than four hours with others, because there are (1.0) four hours throughout a week where we have lectures, and then I work with others during those hours. Er… (2.0) but felt that it fit quite well, yes, how I use it when I work. (Brage 2,7)

On his use of the textbook for the Maxima project, Brage went on to say that the textbook is the easiest way to look up formulas and that he does not use it for much else. During the second interview, he also mentioned using Wolfram Alpha a bit, to check his answers after he has solved an exercise. He clarified that he uses video lectures prior to doing exercises and if he does not understand something after seeing a step by step solution of an exercise. He made several changes to his mind map during the second interview, but did not indicate that any of them represented a change to his use of resources. He did not make any changes to his mind map during the third interview. The SRRS based on the final version of his mind map is shown in figure 4.6.

Brage mind maps seem to paint a picture about his use of resources that is similar to his statements from the interviews. He uses video lectures to get an overview and potentially the textbook for elaboration or to look up formulas. He may also look for other explanations on YouTube or search online when he experiences problems. He works with MyMathLabs, using the step by step solutions, examples and response to wrong answer features. The mind map also shows that he appreciates video lectures and searching online for being quick and the video lectures because he can watch them again.

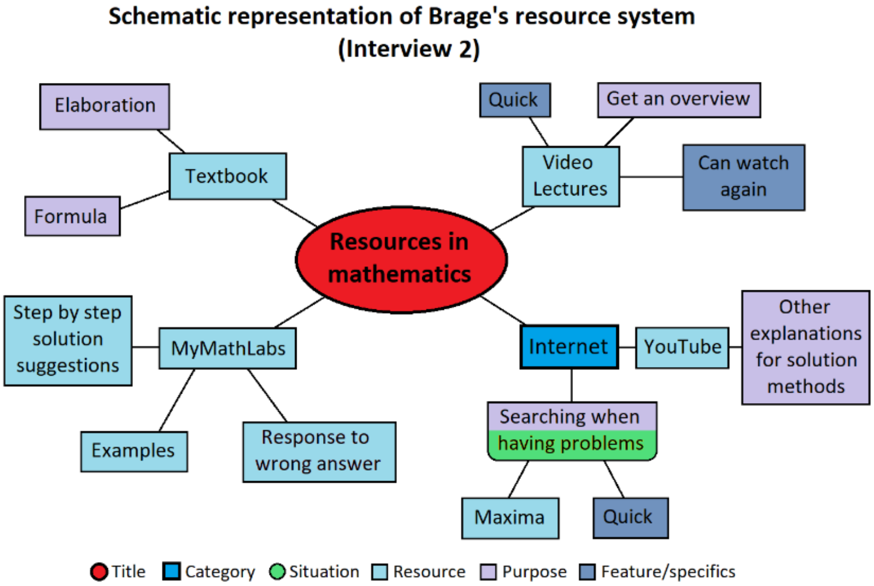


Figure 4.6: The SRRS based on the final version of Brage's mind map. It contains one resource category, eight resources, one situation, five purposes and two features (of which one is repeated).

During the final interview, Brage said he had taken a break from mathematics when working on other exams. Otherwise, the only change to his use of resources was that he had attended more lectures because they had more lectures close to exam, and the lectures focused on problems from previous exams. He said that going forward he would look more at the lecturer's notes and previous exam problems. Regarding resources he felt like he had made his own, he said that he takes screenshots when working on MyMathLabs tests or looking at step by step-solutions, in order to make it easy to find later on. He said that whether it iss in person or by phone or e-mail, he asks questions to friends first, and then potentially asks the lecturer. He said he had asked more questions of people recently.

When Brage was asked how he experienced his participation, he mentioned among other things that he found it useful to be able to check how many hours a week he spent on mathematics. He said that according to the lecturer, they should spend about seven hours a week on mathematics. He said that aside from tests and exam preparation, he rarely works that much. Brage did not fill in any information after the last interview. In total, he worked 57 hours in a span of eight weeks. He worked with others for seven out of 23 sessions. He mislabeled lectures as working alone, making it a bit difficult to say how many lectures he attended. He mostly used textbook, lectures and MyMathLabs, but had several resources he occasionally used, such as YouTube, videos, lecturer, Google and pencil and paper. He used Maxima for two sessions in the same week. Within the last two sessions he filled in, he used notes and formula collection, neither of which he had used previously.

4.2.7 Casper (C1)

Grade: A
Former university experience: None.

I presented Casper with the following summaries about his use of resources during the second interview:

I I have written that every week you start by quickly reading through the wiki pages, then you go to the overview lecture, go to interactive lecture, do recommended exercises and go to plenary or watch videos. You use videos like YouTube or Khan Academy for repetition, use [Charlie's] videos a bit, (1.5) find the book to be a bit heavy and do not use it much. If there is a topic that you need to learn better, you use videos, while you rather use Wolfram Alpha for individual exercises.

C1 That sounds quite right, really. (Casper 2,1)

I I see. Ehm, last time you said that there was no resource that you… felt like you had made your own. (2.0) Do you have anything you would (1.0) add there?

C1 Mm… what do you mean by that question, really?

I Ehm, it is like, if you (0.5) feel like you have found (1.0) ways to use it that no one has taught you.

C1 No, not… (1.5) Not particularly, no. (Casper 2,8)

I When it comes to working with others, have there been any changes to how much you work… with others, compared to alone.

C1 Mm… I have started working a bit more alone (1.5) on certain topics because… I have gotten a bit… – gotten a little diff… – to a different level than the ones one normally works with, so then one is often better of (0.5) working alone, at times. Still realize the value of working with others. (Casper 2,9)

During the second interview, Casper said that he used the math lab more, to get help from student assistants. He said that he occasionally uses Wolfram Alpha, to look at graphs in order to gauge an approximate answer for an exercise. As seen in his comment to the summary, he works less than previously with fellow students due to differences in skill level. He made no changes to his mind map during the second or the third interview. Figure 4.7 shows the SRRS based on his mind map.

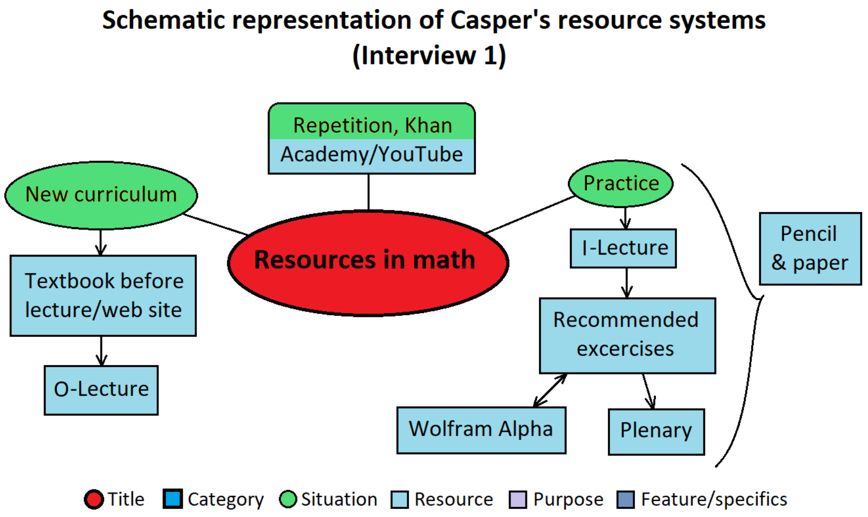


Figure 4.7: The SRRS based on the final version of Casper's mind map. It contains three situations and ten resources. He structured his mind map such that it showed what resources he used in what order in various situations.

During the third interview, Casper said that he used previous exam sets and their solutions a lot in his exam preparation. He said he would use the same strategies for future exam preparations. Regarding new strategies, he planned to take notes differently. Specifically, he wanted to focus on understanding and note down a few important things rather than to try to write everything down. He said that he still works mostly alone, but that sometimes he works with others on difficult tasks.

Discussing Casper's mind map with him revealed that it displayed the order in which he used resources in various situations. For new topics he uses the textbook or the course page, then attend the overview lecture. For repetition later on, he uses videos from Khan Academy or YouTube. To practice he first attends the interactive lecture, then works on recommended exercises, using Wolfram Alpha when necessary. Finally, he attends or looks at the plenary session to compare his solutions and solution methods to those of a university professor.

Casper filled information into the app for eleven weeks, all the way up to exams, but after the first month he neglected to answer the question about resources. For the first eight weeks, he worked for 53 hours, of which 23 were lectures. During the last three weeks, he worked for 76 hours in total. He worked with others for two sessions within the first week and three sessions within the last three weeks. Early on, when he did answer about resources, he listed pencil and paper for seven sessions, textbook for two and Wolfram Alpha, compendium and calculator for one each.

4.2.8 Celine (C2)

Grade: A
Former university experience: None.

I presented Celine with the following summaries about her use of resources during the second interview:

I	What I have written is that you use the textbook, but think it is a bit cumbersome for looking things up, that you attend lectures and take notes. When you work on exercises, you sometimes use Google or check the topic pages at [Charlie's] website. You also sometimes use GeoGebra, particularly for exercises that you got wrong at first.
C2	Yes… Would say so, yeah. (Celine 2,1)
I	Right. Ehm (1.0) when it comes to finding your own ways to use resources, you (1.0) said that you… use plenary videos to solve every exercise on your own first and then look through (0.5) plenary videos. Er (1.0) do you have anything to add to that?
C2	No, I still do that. Because I feel like I learn more by thinking, and not just… be there and listen, right. (Celine 2,8)
I	Mm. Ehm, when it comes to working with others and asking questions and such, I have written that you (0.5) ask a few questions to student assistants, which are concrete questions about exercises, and that you work four to five times a week with everything from two to seven fellow students (2.0) Does that fit rather well?
C2	Yes… Well, I would not say that I ask many questions to student assistants, it is a bit like – a bit, right, but not… (1.0) very much. (Celine 2,10)

During the second interview, Celine said that she had used Google a bit more recently, because she had run into exercises on a familiar form. She also said she uses "internet" less, presumably referring to the course pages (considering she used Google more). She did not make any changes to her mind map during the second or third interviews. Figure 4.8 shows the SRRS based on her mind map. Her mind map only featured the resources used and no situations or purposes.

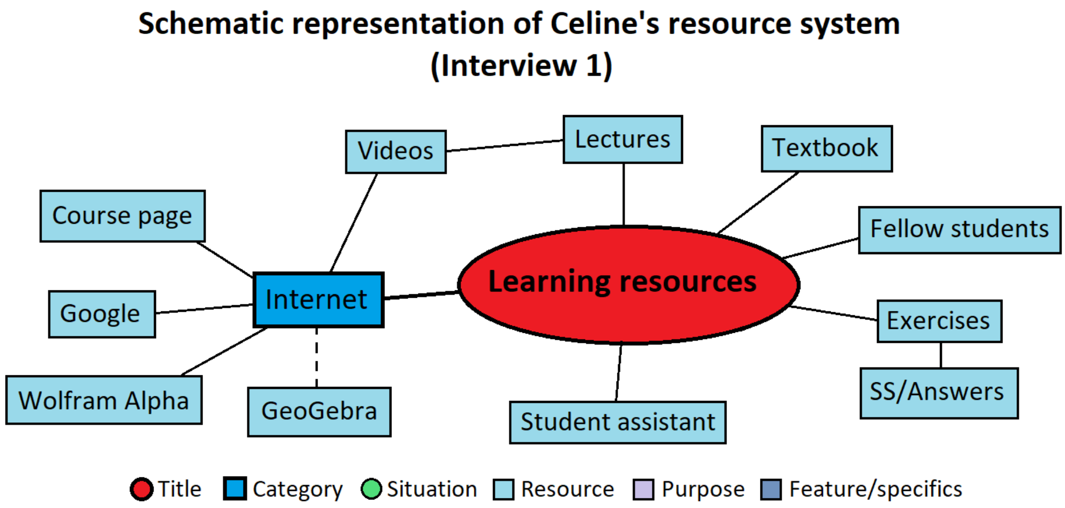


Figure 4.8: The SRRS based on the final version of Celine's mind map. It contains one resource category and eleven resources. SS stands for solution suggestion. She connected internet to GeoGebra with a dotted line, indicating that it did not fully fit within that category, but was somewhat related.

During the third interview, Celine mentioned that she used more of the resources tied to exercises because she had been preparing for exams. The interview was conducted after she had started her next course and she said that she would use student assistants more because the course in question had fewer resources available on the course pages. Otherwise, she did not report any changes.

Celine filled information into the app for three weeks. The 13 sessions added up to 28 hours. She did not label any of the sessions as organized sessions (but presumably several were). She worked alone for seven and with others for six sessions. She used textbook, calculator, and pencil and paper for nearly all the sessions. She also used the course pages and GeoGebra for four sessions each, student assistants for two, and Wolfram Alpha and lecturer for one each.

4.2.9 Christian (C3)

Grade: A

Former university experience: None.

I presented Christian with the following summaries about his use of resources during the second interview:

I	Ehm… (1.0) I wrote that you read the book before lectures, take notes during the lecture and ask the lecturer (1.0) or friends if there is something you are wondering about. You work on exercises either alone, in a group or during group sessions, often watch YouTube about math, but not necessarily curriculum, use Wolfram Alpha a bit, for instance to plot things. Sometimes you Google something. Er, you have not needed it yet, but have considered using (0.5) Khan Academy and YouTube when something becomes difficult. Have not used the summaries or compendium yet, and are not sure whether you will use them. Prefers two different explanations to things, for instance through lecture and textbook. [Christian claps] So… does it fit well?

C3	Mhm, it was actually surprisingly *accurate*. (Christian 2,1)

I	Er, about resources you feel like you have made your own, you said that you (0.5) often wrote on the windows at home, especially when exercises (0.5) looked like they would be… long and difficult. Ehm, are there any more (1.0) you can think of, or… new…?

C3	Mm, I still do that, but other than that, then… (1.0) it looks pretty empty. (Christian 2,7)

I	Mm. Ehm… (1.0) about studying with others, you said that you study two to three times a week, with between two and four others. Ehm, when you work with others you usually sit in a big group, but you mostly work with one other person. (2.5) So, is it about the same?

C3	Yes, it… sounds – maybe I work (0.5) a bit more with – or when I sit with three or four people, like, it happens that we all work on the same, but, er… it is pretty random (0.5) what people work on. (Christian 2,8)

During the second interview, Christian said that he had watched a single Khan Academy video, that he discusses the topics more with friends because the topics was harder and more difficult to understand. He also said that he uses Wolfram Alpha less and Google more for the same reason. Looking at his mind map, he changed ‘math studying friends’ to just ‘friends’, because he has discussions with both mathematics and engineering students. He also changed Googling proofs to just Google because he also uses it for other purposes. Lastly, he scratched summary/compendium and added former exams. He prefaced that the last two changes were the only ones that represent a change to his strategies. His new plan for exam preparation was to heavily emphasize previous exam sets.

During the third interview, Christian scratched Khan Academy from his mind map, saying that he had not used it at all since the last time. Discussing his mind map, he said that he would use Google if he had to look up a trigonometric identity. Lately, he had often used Wolfram Alpha instead of the calculator, so he scratched calculator. Figure 4.9 shows the final version of his mind map, which consists of resource categories and resources. In the rest of the interview, he said that he had used Khan Academy a bit during the exam period to "look for something" when he worked on previous exam sets. He still did not reintroduce Khan Academy into his mind map for the third interview.

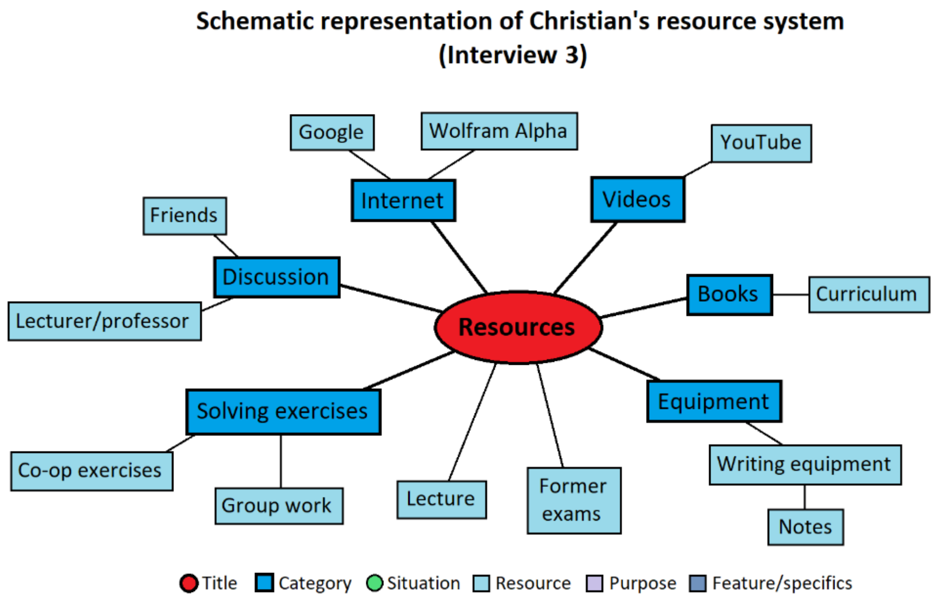


Figure 4.9: The SRRS based on the final version of Christian's mind map. It contains six resource categories and twelve resources. The initial version did not include former exams, but did include Khan Academy, calculator and summary/compendium. It also specified math studying friends and googling proofs, rather than simply friends and Google.

Christian filled information into the app throughout the semester, including the exam itself, in which he listed "snacks" as a resource. Within eleven weeks, he filled in 56 sessions, for a total of 116 hours. At most he worked for 38 hours in a span of two weeks leading up to exams. He worked with others on four sessions, while there were 30 organized sessions. Pencil and paper, textbook, and calculator were used for almost all sessions. Other resources (and the numbers of sessions they were used in) were the lecturer (20); Wolfram Alpha (10); student assistants (6); Khan Academy (2); Internet (2); YouTube (1); videos (1); laptop (1) and snacks (1). Noteworthy is the fact that during the last week of exam preparation he only used pencil and paper, calculator and textbook, while the week prior he also used Wolfram Alpha, student assistants and the lecturer.

4.3 Resource statistics based on the schematic representations of resource systems

This section presents all the resources or resource categories that students mentioned in their mind maps in the manner described in the sub-section 'qualitative analysis on schematic representation of resource systems' (page 80). Some categories were too general to be tied to digital, material or social resources. This included the categories visual, written and auditive.

4.3.1 Digital resources

Table 4.8 shows how many students from each university and in total mentioned various digital resources. We see that digital resources were used a lot at universities Beta and Charlie. At University Alpha, Adrian mentioned some digital resources that the data from the Studert app showed that he rarely or never used. The most mentioned resources or resource categories (mentioned by three or more students) were internet, Wolfram Alpha, videos, YouTube, Google and calculator.

	Hardware	**Non-hardware**	**Other**
University Alpha (n=4)	Calculator: 2 PC: 1	Internet: 2 GeoGebra: 1 Google: 1 Excel: 1 Wolfram Alpha: 1 Automated calculation within Wolfram Alpha: 1	

University Beta (n=2)	Calculator: 0/1	Internet: 1/2 Videos: 1 Video lectures: 1 MyMathLabs: 1 Computer aided assessment within MyMathLabs: 1 Step by step solution suggestions within MyMathLabs: 1 Examples within MyMathLabs: 0/1 YouTube: 0/1 Maxima: 0/1 Simulations: 0/1	Interactive: 1
University Charlie (n=3)	Calculator: 1/0	Wolfram Alpha: 3 YouTube: 2 Course page: 2 Internet: 2 Videos: 2 Google: 2 Khan Academy: 2/1 GeoGebra: 1	
In total (n=9)	Calculator: 3/3 PC: 1	Internet: 4/5 Wolfram Alpha: 4 Videos: 3 Google: 3 YouTube: 2/3 Course page: 2 GeoGebra: 2 Khan Academy: 2/1 Video lectures: 1 Excel: 1 Automated calculation within Wolfram Alpha: 1 MyMathLabs: 1	Interactive: 1

		Computer aided assessment within MyMathLabs: 1 Step by step solution suggestions within MyMathLabs: 1 Examples within MyMathLabs: 0/1 Simulations: 0/1 Maxima: 0/1	

Table 4.8: The digital resources and resource categories mentioned in the mind maps from students at universities Alpha, Beta and Charlie, and in total. 17 different resources or resource categories were mentioned initially and 20 eventually. The total number of mentions were 33/37 (two were removed and six added).

4.3.2 Material resources

Table 4.9 shows how many students from each university and in total mentioned various material resources. Material resources were featured quite equally in the mind maps from each university, when one factors in the sample sizes. The most mentioned resources or resource categories (mentioned by three or more students) were the textbook (which was mentioned by all students), exercises (mentioned by 7 students), pencil & paper (5) and formula collection (2/3).

	Constructed	**Provided**	**Other**
University Alpha (n=4)	Old notebooks: 1 Lecture notes: 1 Exam sheet: 0/1	Textbook: 4 Pencil & paper: 3 Exercises: 3 Formula collection: 1/2 Solution suggestion: 1 Example exercises: 1	Marking important parts within lecture notes: 1 Reading through chapters within textbook: 1

University Beta (n=2)	Textbook notes: 1 Lecture notes: 1	Textbook: 2 Books: 1 Formula collection: 1 Exercises: 1 Tests: 1	
University Charlie (n=3)		Exercises: 3 Textbook: 3 Pencil & paper: 2 Books: 1 Group work: 1 Solution suggestion: 1 Previous exam sets: 1 Compendium: 1/0	Equipment: 1 Notes: 1
In total (n=9)	Lecture notes: 2 Old notebooks: 1 Textbook notes: 1 Exam sheet: 0/1	Textbook: 9 Exercises: 7 Pencil & paper: 5 Formula collection: 2/3 Solution suggestion: 2 Books: 2 Group work: 1 Tests: 1 Previous exam sets: 1 Example exercises: 1 Compendium: 1/0	Marking important parts within lecture notes: 1 Reading through chapters within textbook: 1 Equipment: 1 Notes: 1

Table 4.9: The material resources and resource categories mentioned in the mind maps from students at universities Alpha, Beta and Charlie, and in total. 19 different resources or resource categories were mentioned initially and 19 eventually (one was removed and one added). The total number of mentions were 40/41 (one was removed and two added).

4.3.3 Social resources

Table 4.10 shows how many students from each university and in total mentioned various social resources. Social resources were emphasized at University Charlie, which had more organized events. The most mentioned resources or resource categories (mentioned by three or more students) were fellow students (7), the lecturer (4) and lectures (4).

	People	**Events**	**Other**
University Alpha (n=4)	Fellow students: 4 Lecturer: 3 Parent: 1	Lectures: 2	Human resources: 1 Solution suggestion (from lecturer during lecture): 1
University Beta (n=2)	Fellow students: 1	Lectures: 1	
University Charlie (n=3)	Fellow students: 2 Student assistants: 1 Friends outside the course: 1 Lecturer: 1	Lectures: 1 Overview lecture: 1 Interactive lecture: 1 Plenary session: 1	Discussion: 1
In total (n=9)	Fellow students: 7 Lecturer: 4 Student assistants: 1 Friends outside the course: 1 Parent: 1	Lectures: 4 Overview lecture: 1 Interactive lecture: 1 Plenary session: 1	Discussion: 1 Human resources: 1 Solution suggestion (from lecturer during lecture): 1

Table 4.10: The social resources and resource categories mentioned in the mind maps from students at universities Alpha, Beta and Charlie, and in total. 12 different resources or resource categories were mentioned. The total number of mentions were 24.

4.3.4 Breakdown

Looking at how many resources were mentioned for each category and how many mentions there were in total, we get the statistics of table 4.11. It shows provided material resources and non-hardware digital resources to be the subcategories with the most mentions. More non-hardware digital resources are mentioned, while provided material resources have more mentions per resource on average. Another subcategory that had many resource mentions per resource was people.

Category or subcategory	**N (resources)**	**M (mentions)**	**M/N (mentions per resource**
Digital resources	17/20	33/37	1.94/1.85
Hardware	2	4/4	2
Non-hardware	14/17	28/32	2/1.88
Other	1	1	1
Material resources	19/19	40/41	2.11/2.16
Constructed	3/4	4/5	1.33/1.25
Provided	12/11	32/32	2.67/2.91
Other	4	4	1
Social resources	12	24	2
People	5	14	2.8
Events	4	7	1.75
Other	3	3	1

Table 4.11: Breakdown of how each category and subcategory of resources scored in terms of resources mentioned, number of mentions and the average number of mentions per resource.

To investigate differences between types of resources further, I will divide resources into a classification based on how commonly they were mentioned. Resources and resource categories mentioned by six or more students at least once are considered very common; while four or five students qualifies as common; two and three as somewhat common and resources or resource categories mentioned by a single student are uncommon. In table 4.12, I list how many resources within each category fall within each level of commonality. For uncommon resources, I only list the number of resources. It shows that there are many digital resources that are somewhat common and none that are very common. Material resources feature at every level of commonality and has the most resources that are very common. Social resources stand out by having no resources in the somewhat common range. All the resources are either common, very common or uncommon.

Level of commonality	Digital resources	Material resources	Social resources
Very common (6-9)		Textbook: 9 Exercises: 7	Fellow students: 7
Common (4-5)	Internet: 4/5 Wolfram Alpha: 4 Calculator: 3/3	Pencil & paper: 5	Lecturer: 4 Lectures: 4
Somewhat common (2-3)	Videos: 3 Google: 3 YouTube: 2/3 Course page: 2 GeoGebra: 2 Khan Academy: 2/1	Formula collection: 2/3 Solution suggestion: 2 Books: 2 Lecture notes: 2	
Uncommon (1)	11 resources	13 resources	9 resources

Table 4.12: Resources categorized in order of type and commonality. Shows that there were many digital resources in the somewhat common and common range, but none that were very common. In contrast, no social resources were somewhat common. There were material resources at every level of commonality.

Looking at table 4.12 and considering what resources could be considered emphasized in the courses, I would argue that all the material resources above uncommon could be considered emphasized resources. Lectures could also be considered emphasized, while the degree to which fellow students and the lecturer were emphasized is unclear from contextual data. Among the digital resources above uncommon, I would only consider course page, calculator and videos as emphasized, leaving five resources and one resource category that were not emphasized in any of the courses, yet were mentioned by more than one student.

4.4 Identified themes

In this section, I will discuss the themes I identified in my thematic analysis, and the results that were not mentioned by enough students to be considered a theme, but that are still theoretically significant and worth further study. I organize the themes into seven theme categories, each of which gets a subsection within this section. These theme categories are classes of situations; schemes of utilization; didactical resource purposes; evolution of documents; resource decisions; resource discovery and quality criteria. I also dedicate a short subsection to minor results that did not relate to any of the theme categories. As shown in figure 4.10, three of the theme categories relate to how students make decisions about resources. Within the category resource decisions, the themes establish that students only consider resources that they are already familiar with. I also identify that students make their decisions largely based on what they perceive as suitable for the task at hand, with a secondary consideration of which resources they prefer. Resource discovery deals with how they discovered the resources they are familiar with, while quality criteria deals with what criteria may lead a student to prefer a certain resource.

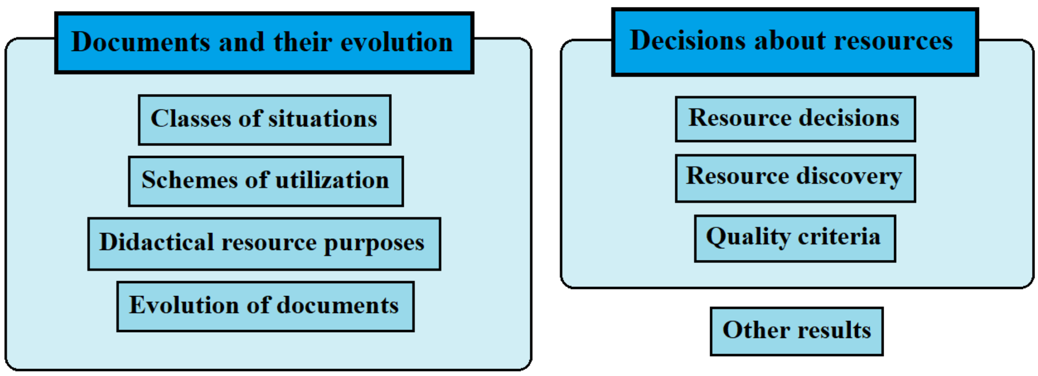


Figure 4.10: The seven categories of themes and an additional category for other results. Three theme categories relate to students' choices regarding use of resources, while four regard their use of resources in a way that can be tied to their documents.

Four of the theme categories were closely tied to the documentational approach (Gueudet & Trouche, 2009). It is central to the documentational approach that a document consists of a set of resources and schemes of utilization. A document is valid for a given class of situations and documents develop over time. The resources are covered across the themes and subthemes. Three of the theme categories are directly tied to such a short summary of the documentational approach, while didactical resource purposes (DRPs) need further explanation, since I am introducing that terminology. In a sense, DRPs can also be considered classes of situation, but at a different level of generality. When I asked the students about their use of resources in various situations, they tended to phrase their answers in terms of what caused them to use resources differently. As discussed in the section on working definitions, I use the term *prime document* to discuss their most regular use of resources. The themes within classes of situations are situational factors that cause the students to employ other documents than their prime document. DRPs on the other hand, can be considered phases within a document. I have derived the name from the fact that students often discussed them through statements on the form “I use resource X for purpose Y”, and from my interpretation that students organize their activity through those phases, in a similar manner to how the documentational approach describes the didactical component of resources.

4.4.1 Classes of situations

About the category

The name ‘classes of situations’ is derived from the documentational approach, where different documents are employed for different classes of situations. My working definition of classes of situations can be found on page 27. The themes within this category specifically relate to situational factors that cause students to use resources *differently than they normally would*. They do not directly describe the class of situations that apply to what I call the students’ prime documents. It can be assumed that the prime document is employed when the students learn mathematics at university and neither of the situational factors below apply. However, an exception to this is the theme ‘working with fellow students’. Some students normally work with their fellow students, so it could be considered part of their prime document. See the student summaries for an indication of the extent to which the individual students work with their fellow students. The statements that inspired this category can be the students simply saying that something affect their use of resources; saying so and additionally detailing the differences or detailing a change to their use of resources recently, giving a reason that I would interpret as a situational factor. Each theme within this category are situational factors that relate to statements from several students. The subthemes relate to the differences in resource use given the situational factor of the theme. The results are situational factors that I identified based on statements from a few students. Table 4.13 shows all the themes, subthemes and results, as well as the number of statements from each student that they were based on.

Classes of situations	**A1**	**A2**	**A3**	**A4**	**B1**	**B2**	**C1**	**C2**	**C3**	**Total**
1.1 Exam preparation	5	1	1	5	4	4	4	2	6	32
1.1.1 Emulating the exam situation	4	1	1	3	2	1	3	1	6	22
1.2 Experienced difficulty	3	1	1	1	1	9	6	2	5	29
1.2.1 Ease leads to use of emphasized resources	Other numbers apply									

1.2.2 Difficulty leads to use of social resources	Other numbers apply									
1.3 Working with fellow students	1	1	0	1	1	1	1	1	1	8
1.3.1 Working with others leads to use of text resources and discussion over digital resources	Other data apply									
1.a Degree of familiarity	0	3	0	0	0	1	0	1	0	5
1.b Lack of time	0	0	0	0	2	0	0	0	0	2
1.c Priority of others	0	0	1	0	0	0	0	1	0	2
1.d Areas of mathematics	2	0	2	0	0	0	0	0	0	4
1.e Working with mandatory assignments	0	0	1	0	0	0	0	0	0	1

Table 4.13: Breakdown of the number or statements from each student that each theme, subtheme and result within the category classes of situations is based on. Subthemes are indented below the theme they relate to. Results are enumerated with letters. For some subthemes, other data will be presented later in the subsection.

Description of classes of situations

Students have a variety of documents, detailing which resources they use and how. When deciding which document to employ, they consider the situation. Based on situational factors, they decide what resources and strategies to employ. Each document is thus employed for a certain class of situations, defined by certain situational factors, such as the nature of the problem or anything affecting each student's capability to deal with the problem. Students tend to have a prime document detailing how they use resources in situations that they consider sufficiently normal. Given certain situational factors, the students will consider the current situation to fall within a different class of situations and thus a different document needs to be employed.

Theme 1.1: Exam preparation

Leading up to the exams, students will employ their exam preparation document.

B1 I try to work as efficiently as possible, because now it… exams are fast approaching (Benjamin 3,5)

While the students' prime documents are mostly concerned with learning new mathematical topics, their exam preparation is about solidifying their knowledge and preparing for the task of undergoing the exams. In exam preparation, they also evaluate themselves and how well they are currently equipped for the task of taking the exam.

A1 I think it is more that… (1.0) that I go from to… (1.0) being in – what to say – the learning phase where I (0.5) learn new things to being in the exam study phase where I just (0.5) challenge myself and like, test in every way, and it is, like… (1.0) two different ways to do things. (Adrian 3,4, regarding the changes to his resource use that he reported in response to the previous question)

Documents are very individual, so exactly what the exam preparation document entails depends on the individual student. Strategies include looking at videos for repetition on mathematical topics that have been covered; working more with fellow students; working more on exercises and working more in general. Based on app data, Benjamin and Christian worked almost twice as many hours a week during exam preparation while Casper worked more than three times as many hours. For other students, there was no data from the exam period. While there were individual differences, several of the changes to the students' mind maps seem to indicate that they were practicing for exams by emulating the exam situation, which I identify as a subtheme.

Subtheme 1.1.1: Emulating the exam situation

In order to prepare for the task, and evaluate their own capability to overcome the task of exams, students have a tendency to work under similar conditions to the exam itself. For instance, the students work on problems from previous exams, and they work more with resources that they can bring to the exams, such as the formula book, and in the case of University Alpha, a self-written sheet of paper with notes. Adrian added formula collection to his mind map during the last interview, while Anna added exam sheet and Christian added former exams.

C3 The difference between when I work during the exam period and when I work normally, it is that in the exam period I usually just do exam sets. (Christian 3,3)

In the case of Adrian, he directly emulated the exam situation by only using resources that were allowed at the exam when he worked on former exams.

A1 Of course, at exam tasks when I am (0.5) attempting them, I of course do not use (0.5) internet and talking with friends and such until I am done, because then the thing is to test oneself a bit first, then it is just (0.5) calculator and… (1.5) er… (0.5) pencil and paper and (2.0) or, formula collection that is allowed. (Adrian 3,1)

In some cases, the resources emphasized in the courses were also tailored to the exams. Both at University Beta and University Charlie, some video lectures covered previous exam problems. Before exams at University Beta, students reported that there were more lectures and that the lectures focused more on exam problems.

B2 Er, now lately, I have been attending l… – lectures – or we have had more lec… –lectures (1.0) with [Bjørnsen] in class, or we have gotten an extra hour a week, right, where he goes through (0.5) problems that are relevant for exams and such (Brage 3,3)

Theme 1.2: Experienced difficulty

Students often find that when they considered a mathematical task to be difficult, they needed to use other or additional resources. The students in the study gave a variety of statements indicating which resources they normally use and which they use when they experience difficulty. After all, in mathematics it is usually quite easy for a student to gauge whether they successfully completed a task or not. Students usually try to employ their prime document first, and if they are unsuccessful, they employ different resources and schemes. The participating students often used direct comparison between resources that they used for similar goals in their statements. In Anna’s mind map, she said that she may use the solution suggestions when she is unsuccessful at solving an exercise, while Brage’s mind map communicates that he searches for answers on the internet when he has problems.

A4 If (1.0) there is something I do not fully understand, even if I have gone… through the notes and the book, it might happen that I (0.5) search the web for a different explanation, right. And such. (Anna 1,3)

B2 To find other solutions or other explanations if I think video lectures are hard to understand and the tex… – textbook can be a little bit (0.5) heavy to read sometimes. Then it is usually (1.5) like YouTube [Writes] or something like that that I go to. (Brage 2,11, when updating his mind map)

C1 Then I use mostly pencil and paper, right, and then (1.0) potentially Wolfram Alpha if er… (1.0) they are recommended exercises that I struggle with. (Casper 1,1)

Looking at the resources they mentioned, I identify two subthemes. That the students use emphasized resources more often when they consider the task to be easy and that they use social resources more often when they consider the task to be difficult.

Subtheme 1.2.1: Ease leads to using emphasized resources

Students' prime documents seem to consist largely of emphasized resources, while experiencing difficulty makes them more likely to employ resources that are not emphasized in the course they are attending. Table 4.14 shows all the resources and resource categories that were mentioned related to which resources students use normally and which resources they use when they experience difficulty. It also shows whether, to my understanding, the various resources mentioned are emphasized in the courses. While, some resources are emphasized at some, but not all universities, there were no example of students using a resource that was not emphasized at their university, but was emphasized at a different university. Thus, there was no need to differentiate based on what university each resource was emphasized at.

Resource	**Emphasized?**	**Students using it normally**	**Students using it given difficulty**
Textbook	Yes	6	2
Calculator	Yes	2	0
Pencil & paper	Yes	2	0
Notes	Yes	2	0

“What is at hand”	Yes	1	0
Lecture	Yes	2	0
Video lecture	Yes	1	2
Emphasized resources in general	Yes	1	0
MyMathLabs examples	Yes	1	1
MyMathLabs exercises	Yes	1	0
Exercises	Yes	1	0
Course pages / math wiki	Yes	1	2
Fellow students	Unclear	3	5
Lecturer	Unclear	0	3
Old math books	No	1	0
“More resources”	No	0	2
Internet	No	0	3
CAS tools	No	0	1
Wolfram Alpha	No	0	2
Google	No	0	3
YouTube	No	0	3
Khan Academy	No	0	1

Table 4.14: The number of students who mentioned using various resources normally and when they experienced difficulty, based on statements about difficulty affecting resource use. Also indicated is whether the resources were emphasized in the courses that the students who used them attended. Shows that emphasized resources are generally used more for tasks with normal difficulty and that non-emphasized resources are used more when students experience difficulty.

Given the information from table 4.14, one can add up the numbers for the emphasized and non-emphasized resources to get a total of mentions of emphasized or non-emphasized resources used normally and used when experiencing difficulty. When doing so, I ignore any instance of the same student mentioning the same resource an additional time. As table 4.15 shows, there are three times as many mentions of using emphasized resources normally compared to using it when experiencing difficulty, and there is only one mention of using a non-emphasized resource normally, while there are 15 mentions of using non-emphasized resources when experiencing difficulty.

	Emphasized resources	Non-emphasized resources
Normally	21	1
Given difficulty	7	15

Table 4.15: When ignoring the same student mentioning the same resource additional times, there were 21 mentions of emphasized resources used normally and seven mentions of emphasized resources used when experiencing difficulty, while the same numbers for non-emphasized resources were one and 15, respectively.

Students did not discuss why they used more emphasized resources normally and more non-emphasized resources when working with others, but several interpretations could be considered. From a socio-cultural perspective, one might pose that the students normally use emphasized resources because of their significance within the socio-cultural context of the course and the students' desire to fit in. If one assumes that the students are more pragmatic, one could argue that the students trust the judgement of the course organizer(s) and assume these resources to be an effective way to acquire the skills and knowledge that are measured during exams.

Either way, the reason they use non-emphasized resources when experiencing difficulty seems to be that they have already tried the emphasized resources without success.

Subtheme 1.2.2: Difficulty leads to using social resources

The two resources in table 4.14 that are not labelled as either emphasized or non-emphasized are both resources I would classify with the category social and the subcategory people. Five students mentioned working more with fellow students when they experienced difficulty.

B2 It has been a bit harder recently, so I might say that I ask a bit more for help lately. Cooperates more with buddies and such. (Brage 3,7)

C3 If there is something I do not understand, I usually talk to the professor slash lecturer or discuss it with friends, potentially googling it on my own afterwards. (Christian 1,1)

Three of those five students at some point made a statement that when they experience difficulty, they ask the lecturer rather than fellow students. Hence, they were also labeled as saying that they used fellow students normally.

Looking at which four students never mentioned using fellow students or the lecturer more, three of them are students who did not report using social resources much to begin with (Adrian, Benjamin and Casper). It may be that the subtheme mostly holds true for students who use fellow students and the lecturer as resources on a regular basis. One of the advantages of using people as resources, is that they help both with interpreting new information and solving tasks. This may be one of the reasons why students work more with each other when they experience difficulty. Another may be affectional issues. One interpretation could be that a sense of community is more important to students when they experience difficulty and may need to 'lift their spirits'.

Theme 1.3: Working with fellow students

When students work with fellow students, they often use resources differently than usual. Eight out of nine students answered (when asked) that they use resources differently compared to when they work alone, including students who did not work with fellow students very often. I would summarize each of their descriptions of the specific differences as follows:

- A1: Mainly uses discussion with fellow students to check his work, rather than resources for the same purpose such as Wolfram Alpha.
- A2: Uses her old math books less and the textbook more when working with others.
- A4: Uses internet less for checking her answers and fellow students more.
- B1: Uses videos less and exercises, textbook and web pages more.
- B2: Uses videos less and asking fellow students more.
- C1: Uses videos less and *oppslag* more. ("Oppslag" is a Norwegian word for looking something up that may here refer to a word search section in a book).
- C2: Uses internet less.
- C3: Uses textbook less and lecture notes more.

As an example, the above summary for student B1 is derived from the following statement:

B1 Yes… When I work alone, then… (1.5) there are those videos, for instance, right, when I work with others it is mostly ehm... (2.0) do the exercises, for instance we are to do and then it is just to… do them and then potentially look at formulas and look at… like, small elaborations in books, ore online or [inaudible] where one can find examples of how (0.5) those exact problems are solved, for instance. (Benjamin 1,12)

As one can observe from the summaries above, there are great individual differences. However, I consider it to be a subtheme that digital resources are generally used less, and replaced with text resources and discussion.

Subtheme 1.3.1: Working with others leads to use of text resources and discussion over digital resources

Students generally use resources that required the computer less when they work with others than when working alone. One reason for this may be that students usually sit around a table when they work together. Computer screens may make communication difficult because it is harder to establish eye-contact with someone across the table. Also, using the computer and asking others may serve similar purposes (such as finding information), with fellow students being the preferred resource. The students' comments did indicate that discussion with fellow students is important when they work with them.

A1 If I work with others, then they are also (0.5) resources… in a way. Ehm (1.0) If we are several, then it is (1.0) quite nice, because then you can (1.0) get them to check if you have done some idiotic things along the way and that is why your answer is wrong. That one has (1.0) dropped… dropped a parenthesis or something, or... (0.5) forgot the sign. (Adrian 1,2)

The textbook may be preferred, because if all students have it available, it may be easier to read the same content, by simply giving each other the page number. When students work with others, they may prioritize resources that enable efficient communication.

Some findings within classes of situations were not mentioned enough for me to label them as themes, so I call them results:

Result 1.a: Degree of familiarity

Three students indicated that they have different strategies depending on the degree to which the topic at hand is familiar to them. Amalie mentioned using her old math notebooks.

A2 Well, if there are new topics, I usually use the textbook to read up on the material and (1.0) figure out what to do and such. While if there are old topics – or topics that we have had then (1.0) I look at what I have done, right. (Amalie 1,12)

Brage mentioned that his reason for using the internet particularly much when he worked with Maxima, was that it was so unfamiliar to him. Celine mentioned using Google to look something up when it relates to a topic she is familiar with from secondary school.

Result 1.b: Lack of time

This result was identified exclusively based on statements by Benjamin. He reported that lack of time to spend on mathematics was a big problem for him, and caused him to use different strategies than he would otherwise. He chose strategies that he considered efficient, rather than thorough. He also did not do many exercises, as witnessed in the app data from him.

B1 Ehm, if I have good time, then… I sit down with the videos, and go through them, like, thoroughly. Ehm… (1.5) If not, I just have to (1.0) read in the textbook, and then (0.5) attend the lectures that have been scheduled. (Benjamin 1,3)

Result 1.c: Priority of others

The availability of social resources is an issue to Celine and Andreas. Celine reported that how much she works with other depended on the priorities of her fellow students.

C2 And then we have, that prioritized time for math lab (0.5) on Tuesdays, so I usually go there, right, and then maybe more (0.5) slightly dependent on (0.5) time and what others do and such. (Celine 2,11)

Andreas found that he was unable to find times when he and the people he tended to work with could work on mathematics together. This caused him to work with fellow students less than he would prefer.

Result 1.d: Areas of mathematics

The differences based on the type of mathematics appears to be rather small within the courses in the study. When students were asked whether their resource use varied from topic to topic, no one said there was any difference within the calculus course they currently attended. Adrian, however, added that he would have used resources differently if there were geometrical topics as well. His mind map also reflects this with the item "Geometry in GeoGebra". Andreas mentioned that he would have used Wolfram Alpha or GeoGebra more if there were more tasks for which he would have appreciated a visual representation.

A1 I have not used, er… (1.0) GeoGebra that much for mathematics […] has not been much geometry recently. (Adrian 3,3)

Result 1.e: Working with mandatory assignments

This result was identified exclusively based on a statement from Andreas, although he claimed that the same was the case for several of his fellow students. Andreas said that both he and other students in the course, when they have mandatory assignments, work more with fellow students and are more likely to work with people who they do not usually work with.

A3 For instance, assignments make it so we (0.5) as a class (0.5) er… usually sit with people we do not sit with usually, to try to work and (1.5) get through the assignments as well as possible (Andreas 1,4)

Types of themes

During the first interview, I asked how the students used resources differently in different situations. Many of the statements that informed this category of themes came from replies to this question and a considerable amount of the statements came in response to open questions. Statements regarding the exam preparation were often in response to questions during the last interview about how their use of resources had changed since last time and why. To students from University Charlie, I asked specifically about their exam preparation if they did not initially mention it, because the last interview with them took place after the course was finished, and some of them described instead how they used resources in the new course. I did ask more specifically about whether they used resources differently when they worked with others compared to alone and whether they used them differently depending on the topic.

I would argue that the theme working with others and the result areas of mathematics are more deductive than inductive, since the statements that relate to them came in response to questions I asked based on working hypotheses. I consider the other themes, subthemes and results to be identified inductively. However, there is a possibility that my interpretation that students have a prime documents is not fully inductive. The way I phrased the initial question may have been leading if interpreted differently from how I intended. I asked students what resources caused them to use resources differently. I meant that the use may differ between the situations mentioned. However, I realize that students could have assumed that "differently than normal" was implied from my phrasing.

In terms of semantic or latent themes, most of the themes are in a grey-area. One could argue that they are all latent, because no students knew or used the terms class of situations. However, there are statements were the students specifically said that they used resources differently when they prepared for exams. I think it can be argued that if we treat the question of semantic and latent themes as a continuum rather than a binary choice, all the themes are near the middle, except that experiencing ease leads to using emphasized resources. It is quite a latent theme, since I had to reflect on the resources that were used more and less to identify the predominance of emphasized resources normally and non-emphasized resources when experiencing difficulty.

4.4.2 Schemes of utilization

About the category

I am adopting the name 'schemes of utilization' from the documentational approach. After the initial identification of themes, I originally had two theme categories known as 'resource strategies' and 'appropriation', which I decided to combine and rename. The student statements that count towards this theme include statements on how they use certain resources, and statements about their views on learning and the rules they tend to follow (theorems-in-action). While one can argue that schemes are informed by the socio-cultural context, personal interpretation is a large factor, resulting in a large variety of schemes. Nearly all the themes and subthemes within this theme categories concern great variety in strategies from student to student. As such, a lot of excerpt will be used in order to demonstrate said variety. Table 4.16 shows how many statements from each student each of the themes and subthemes was identified based on. For some subthemes, other numbers apply, which will be presented in their sub-sections. I was uncertain whether to include the strategies for taking notes as a result or a subtheme. I reasoned that while they did not specify strategies for how they took notes (and are thus not represented in the table), Celine and Christian also mentioned taking notes, so eight out of the nine students took notes or used old notes in one form or another. Hence it was included as a subtheme. There is some overlap between the statements that count towards variety of strategies for working with others and the statements that count towards working with others (within the theme category 'class of situations').

Schemes of utilization	**A1**	**A2**	**A3**	**A4**	**B1**	**B2**	**C1**	**C2**	**C3**	**Total**
2.1 Various schemes for working alone	8	2	4	2	2	4	6	6	5	39
2.1.1 Strategies concern a variety of resources	Other numbers apply									
2.1.2 Various schemes for taking and using notes	1	1	1	1	1	0	1	0	0	6

2.2 Various schemes for working with others	2	2	7	4	4	3	3	2	3	30
2.2.1 Generally, groups of three or four are the most common	Other numbers apply									
2.2.2 Extent of working with others compared to alone varied	Other numbers apply									

Table 4.16: Breakdown of the number or statements from each student that each theme and subtheme within the category schemes of utilization is based on. Subthemes are indented below the theme they relate to. For some subthemes, other data will be presented later in the subsection.

Description of schemes of utilization

Students need strategies for how to use their resources to achieve their learning goals. Several people and other features of the context can influence their goals and their development of strategies. However, the students themselves eventually arrive at their strategies based on their interpretation of the context and the effectiveness of various strategies for achieving their goals. Thus, the students develop a variety of different strategies, and one is unlikely to find two students who have the exact same strategies.

Theme 2.1: Various schemes for working alone

When working alone, students employ a variety of schemes, in accordance with a variety of theorems-in-action. Adrian expressed seeing many of the emphasized resources as important, saying they are “actually mandatory” in order to do well in the course. In addition to them, he had developed several strategies for using GeoGebra.

A1 As soon as it comes to things like that you have (1.5) all those points, check that it does not lie on – or that – Check if all the points lie (1.0) Er, on this and that geometric object, defined by (1.0) those three points, of the four points. Then it might be really nice to just stick it into GeoGebra when one is done, and then che… – see that (0.5) ‘oh, no wait, that point, it was actually not (0.5) in… on that plane’ and so on. (Adrian 1,9)

Amalie expressed that she thinks mathematics is mostly about exercises. Most of her strategies concern how to solve exercises.

A2 Well, when I do exercises then (0.5) I look at (0.5) how I have calculated it before, then I find that – like, I need to like, *refresha* (0.5) my memory on how I (1.0) solve it. However, it is much easier to then (0.5) get back into how I solve the exercises when I see how I have done it before, because then it is myself that has done it and not just, like, something I read in the book. I think it is easier to learn if I do many exercises, than if I just sit and read a lot of theory. (Amalie 1,8)

In the beginning, Andreas tried to attend every lecture and watched the streams if he missed one so he would not have to attend a lecture without watching the previous one. After he switched to mostly watching the streams of the lectures, he developed some strategies for how to watch them.

A3 And then I can control the pace to my preference, if there is something I am unsure about then I can stop it completely. Potentially if there is something I have (0.5) an understanding for or under control, then I can (0.5) increase the speed of the (0.5) playback. And I think it is an, er… efficient way, for me, to learn. (Andreas 3,6)

One of Anna’s strategies is to develop her exam sheet by comparing the lecturer’s notes and the formula collection. Adrian has a similar strategy, but comparing the previous exams to the formula collection.

A4 I have gone through the lectures, from the notes, and then I compare with what it says in the formula collection so I do not get anything redundant. (Anna 3,8)

Benjamin relies heavily on the video lectures and has developed several strategies for them. For instance, we watches some part multiple times and some parts at increased speed, while he skips other parts. Sometimes he takes notes when he watches them. Some videos he would watch in their entirety, while others he would watch more selectively.

B1 Well, at least on the introductions I see the whole thing, and then for the rest I skip to the parts where I am uncertain – uncertain to look at precisely the (1.0) steps that I am uncertain about. (Benjamin 3,7)

Brage also likes to increase the playback speed on the video lectures. He also works a lot with MyMathLabs and often takes screenshots.

B2 When I go through tests and such in MyMathLabs (0.5) er… then I always take – or after I am done, right, then I take *screenshot* of the exercises, so I will have it in a systematic way so I can easily go to check an exercises if there is something that I am stuck on. Er, I do the same with (1.0) all exercises that I think are hard, then I s… – *screenshoter* (1.0) the solution suggestion, right, so I will have a *step by step* walkthrough (1.0) of the exercise that I can easily find. (Brage 3,6)

Casper uses the math wiki more than the textbook, and when he watches videos, he often skips to the parts he is interested in. He also has strategies tied to his use of Wolfram Alpha:

C1 If it – often if there are graphs that I am unsure about (1.0) or (1.0) things I want to check how a graph looked like or such, then I use it to draw the graph. Then I can see approximately where the answer will be. (Casper 2,7)

Celine has a variety of strategies regarding various resources. She will always watch the interactive lecture in person, but she watches the videos of the plenary to be able to alternate between solving an exercise and looking at the solution. She occasionally uses Google to look up something. Sometimes, she uses GeoGebra to divide a problem into multiple parts and try to locate where her solution method did not work.

C2 Last week there was an exercise I did not understand why I got wrong, so then it was to use GeoGebra to check why I got it wrong. It was integration, right. So could, like, check if – where the mistake was, right. And, like, divide the exercise and such. So I use it a bit to check, right. (Celine 1,14)

Christian usually reads the textbook before the overview lecture, and said that he did the opposite at upper secondary school. He has a variety of strategies for Wolfram Alpha, related to, for instance, derivation or special geometry. He expressed that his most original strategy was to write on his windows.

C3 I have a resource I often use that is very genuinely me, I feel, and it is that I often write stuff on the windows at home, so the windows at home are filled with mostly math exercises and a couple fun facts, quotes and stuff that I have with my *roomen*, but when I solve difficult exercises that are quite long, if I do no… – if I see that it will – that there is a chance to make a mistake, then I will write it on the window first, where it is easier to erase and edit things and… and then I usually write it down in my book afterwards. And then it is more fun to write on the windows, of course. (Christian 1,5)

Some strategies can also be derived from the mind maps of certain students, depending on whether they chose a mind map structure that includes purposes. For instance, Adrian mentioned using the textbook for finding exercises, for looking up formulas and for repetition. Andreas mentioned using pencil and paper to learn notation; looking to the lecturer as well as the textbook for "academic progression" and "academic depth" and using Wolfram Alpha for graphical representation. Anna mentioned using the parts of the lecturer's notes that she had marked as important for repetition. Benjamin linked the purpose "chance to ask questions" to the lecturer. Brage mentioned that he searched online when having problems; that he used video lectures to get an overview and that he used YouTube to get additional explanations.

I identify two subthemes relate to students' strategies for working alone using various resources. One is that their strategies involve a great variety of resources, and one is that they have a variety of strategies for how to take notes.

Subtheme 2.1.1: Students' schemes for working alone involve a variety of resources

What resources students use varies. Several different resources were mentioned in the participating students' discussion of their strategies, and among those resources few of them were mentioned by a large number of students. For each resource, table 4.17 shows how many students discussed their strategies with that resource.

Resources for which three students mentioned their strategies	Lectures; lecture notes; video lectures

Resources for which two students mentioned their strategies	Textbook; videos of organized sessions; GeoGebra; Wolfram Alpha; exam sheet
Resources for which one student mentioned their strategies	Folder for notes; video notes; old math books; MyMathLabs; course wiki; Google

Table 4.17: Within statements concerning how they used various resources, students mentioned 14 different resources, of which none were mentioned by more than three out of the nine students.

The variety of resources used, as well as the variety of schemes of utilization, show the differences between the documents of individual students, reinforcing the idea that the process of interpretation leads students to use resources differently.

Subtheme 2.1.2: Variety of schemes for taking or using notes

Benjamin took notes when he watched videos. Amalie used her old notebooks for familiar topics. Adrian, Andreas, Anna, Casper, Celine and Christian took notes during lectures. Andreas, Anna and Casper discussed some of their strategies for taking notes, while Adrian discussed his strategies for organizing his notes.

A1 I do not like (1.0) to have different (1.0) er, notebooks for different courses. Because then it ends up with – either way with (1.0) 'oh, shit, did we have math today?' or 'oh, no, was that what the physics notebook looked like?', and then… ends up with hav… – writing math notes in the physics book and physics notes in the statistics book and so on, and so on, so then I rather just bring enough… er, enough notebooks, er… (0.5) with squares or lines that I can write the notes. And then, when I reach a certain milestone where it is no longer… reasonable to have (1.0) all the notes from the previous lectures in… in this (0.5) notebook, then I put it in a folder. (Adrian 3,15)

A3 Notes are put up. Er… I try to avoid (0.5) using those notes. Er… I guess I have not used those notes at all. Instead I attend the lectures and then I see through the lecture and write down notes. I try to note everything that the teacher presents on the blackboard. (Andreas 2,11)

A4 After the lectures I go through and mark what I… (0.5) consider important, and then I also see it when I do exercises, what is important. (Anna 3,12)

B1 If there are things I need multiple times, then like (0.5) I see it several times and take notes during it and… (1.5) then (0.5) repeat er… (2.0) exactly that small part of the video again and again, and then I might skip past the rest. (Benjamin 1,5)

C1 It is more about me… going to try… to get more understanding in the overview lecture while I am there, rather than to note down everything, so try rather to note down the example, because it is mostly what one goes back to to (0.5) find again, right. It is not the definitions one (1.0) wond… – want to check again. (Casper 3,6)

Taking notes, especially during lectures appears to be central to many students' documents. A possible reason may be that lectures only happen once, and taking notes helps the students retain some of the important information in order for it to be available to read at any point later.

Theme 2.2: Variety of schemes for working with others

Students shared a variety of strategies for how they worked with others, either through the interviews or through their mind maps. Both the extent to which they work with others, how and why they work with others vary. Here, I will mention strategies that students mentioned by students in alphabetical order. Neither Adrian nor Amalie specifically mentioned strategies for how they worked with others, they just addressed the extent to which they worked with others. Andreas is rarely able to work with others, even though he prefers to do so and said that he worked less when he had to work alone. He discussed how he would prefer to work when he worked with others:

A3 I like the most to work in a (0.5) active and (1.5) well (0.5) coope… – cooperatively minded group, people who like to talk, people who like to (1.5) shoot ideas. Er… That is probably the environment I enjoy the most. (Andreas 1,9)

Anna mentioned that she and her fellow students do not make an effort to keep the same pace when they work together. Benjamin does not work much with others, even though he said it is "better" and mentioned learning a lot through explaining to others:

B1 It is of course better to work with others than – when one solves exercises and such. Er, for me it often comes down to getting to explain to others (1.5) and it makes it so I get a better understanding of things (1.5) Ehm… (0.5) so what I usually – that is usually the best way to work for me personally. (Benjamin 2,6)

Brage works a lot with others, although he likes to ponder the questions on his own first. Casper works less with others when he feels like there is a disparity between his mathematical skills and those of his fellow students.

C1 Mm… I have started working a bit more alone (1.5) on certain topics because… I have reached a diff – reached a slightly diff… – a different level than those I usually work with, so I get more out of (0.5) working alone, at times. (Casper 2,9)

Celine works a lot with others, but did not share specific strategies. Christian revealed that when he works with others, he will often sit in a larger group, but only interact with one other student.

Some schemes for working with fellow students were also evident from the mind maps. Adrian's mind maps communicate that he uses fellow students for help to check the right answers or when he struggles with something. Andreas' mind map communicates that he works with others both to learn and to teach, and that he solves exercises with them. Anna's mind map includes the purpose "work with and compare methods and answers" linked to fellow students.

Subtheme 2.2.1: Generally, groups of three or four are the most common

All the students were asked how many people they usually work with when they work with fellow students. They all gave answers that included an interval of numbers. Table 4.18 shows the intervals of group sizes (including themselves) that each student gave. Three and four are the group sizes that the most students included within their intervals.

Eight students										1
Seven students										1
Six students										2
Five students										3
Four students										7
Three students										8
Two students										3
Group size	**A1**	**A2**	**A3**	**A4**	**B1**	**B2**	**C1**	**C2**	**C3**	**Total**

Table 4.18: Students had intervals of group sizes for when they worked with others. While the groups sizes ranged from two to eight, the most commonly included group sizes were three and four.

Andreas also stated that he does not enjoy working in particularly large groups.

A3 Usually we are… three to four people. I try to avoid that it becomes too many, as it (0.5) becomes too much noise and distractions. (Andreas 1,14)

Subtheme 2.2.2: Extent of working with others compared to alone varied

While all students expressed a positive view on working with fellow students, the extent to which they did so varied. Looking at the students' statements about the extent to which they worked with others, I labelled each statement as suggesting that the student either work more alone, work more with others or work a lot both alone and with others. This resulted in table 4.19. It shows Adrian, Andreas, Benjamin and Casper to work more alone and Amalie and Celine to work more with others. In Casper's case, he said during the first interview that he worked a lot with others as well, but during the other interviews he said he did not.

	A1	**A2**	**A3**	**A4**	**B1**	**B2**	**C1**	**C2**	**C3**	**Total**
More alone	1		3		1		2			7
Both alone and with others				1		2	1		2	4
More with others		1						1		2

Table 4.19: Four students gave statements that they mostly worked alone and two gave statements that they mostly worked with others, while four gave statements suggesting that the time spent was roughly equal.

Amalie provides an example of a statement expressing the comparison between time spent working alone and with others:

A2 I work more with others than what I do alone, but I feel like I learn better then. (Amalie 1,16)

While the students' use of fellow students as a resource varied, most were quite successful in the course. For instance, at University Charlie, one student worked more with others, one more alone, while one worked both with others and alone and they all got the grade A. While the sample size is too small to draw conclusions, it is interesting to note that only female students said they mostly worked with others and only male students said they mostly worked alone.

Types of themes

During the first interview, every student was asked about how much they work with others, how many they work with and whether they used resources differently when they work with others. In the other interviews, I also asked for changes to how and how much they work with others. Students talked about strategies for when they work alone in response to open questions and questions about resources that they had made their own. For each student, I also picked one resource that I wanted them to talk more about during the final interview, so some comments came in response to that.

Most of the themes and subthemes within this category are latent themes. Students did not use the terms schemes, and did not discuss how they thought their strategies may compare to those of others. The one subtheme I would consider semantic is the one about group size.

I consider all the themes and subthemes within this category to be identified inductively. I did not go in with working hypotheses about the degree to which the students' strategies for using resources would vary or what group sizes would be the most common. While some questions were more open and some more closed, none of the questions that the statements came in response to were biased towards particular answers.

4.4.3 Evolution of documents

About the category

In the documentational approach, teachers' documents evolve through a process called documentational genesis, and a theoretical assumption for the project was that the same would be true for students. Through the course of the project, the students rarely gave statements about the process that lead to their strategies being updated, focusing mainly on the changes themselves. That is the reason why I did not name this theme category 'documentational genesis'. This theme category mostly covers the extent to which documents change over certain periods of time and what factors are likely to cause it. Table 4.20 shows the number of statements from each student that the themes within this category were identified based on. Statements that count towards this theme category came from questions to students about how various aspects of their resource use had changed. The students' answers to what caused the changes and whether they were changes with long term effect, are taken into account. The changes to students' mind maps and how the students described them are also considered, as well as the extent to which there were noticeable changes to the data they filled into the app. For low degree of change within a stable context, the statements counted are the ones that suggest changes within a stable context, and the theme is that there are few of them.

Evolution of documents	**A1**	**A2**	**A3**	**A4**	**B1**	**B2**	**C1**	**C2**	**C3**	**Total**
3.1 High stability of documents	4	2	2	3	3	6	2	6	4	32
3.2 High degree of changes through adaption	1	0	4	0	2	2	1	1	3	14
3.3 Low degree of changes through reflection	0	0	0	1	0	0	1	1	1	4

Table 4.20: Breakdown of the number or statements from each student that each theme within the category evolution of documents is based on.

Description of evolution of documents

Students' use of resources changes over time, both in terms of what resources they use and in terms of their schemes of utilization. Changes can occur within a rather stable context, by virtue of students employing a document and then reflecting on their use. Changes can also come in response to changes to the institutional influences that students need to adapt to. Not all changes to students' use of resources constitute changes to their documents. Students have schemes for a variety of classes of situation. If changes to the context lead to one of their documents being used more frequently, then it is a change to their use of resources, but not to their documents. It is only a change to their documents if they encounter a new class of situation and create a new document; update what resources they use within a class of situation or develop their schemes of utilization for a given class of situations. Students' documents are quite stable within stable contexts, but are developed in response to changes to the context. Taking into account all the themes within this category, documents seem to be updated rather quickly in response to a change to the context, and then remain quite stable until there is a new change.

Theme 3.1: High stability of documents

Students' documents rarely change within a stable context, and the socio-cultural context of a university can be quite stable, leading to little change through the course of a semester. Minor changes might happen all the time, but go unreported given the design of the study, because the students are not aware of them or do not consider them significant enough to be worth mentioning. For instance, as the students become more familiar with a textbook, they may be more selective about what they read within it. Students are likely to primarily report major changes to how they use certain resources; changes to the extent to which they use certain resources and changes to what resources they use. As such, students usually report using resources in mostly the same way as they did at the time of previous interviews.

A2 No, using the same ways to learn things that, really (1.0) that I have always done. (Amalie 3,1)

They also report some changes that only seem to activate other documents. For instance, Anna reported working more with others.

A4 Er… I work more with others, maybe. (Anna 2,2, in response to whether she use any resources more or less)

When asked why that was, Anna simply said it was due to more people being willing to work, theorizing that they were motivated by increased difficulty. My interpretation based on all the interviews with her, is that she would have worked more with other previously, had she been able to.

Data from mind maps and the *Studert* app did not suggest many changes either. Combined, the students updated their mind maps eight out of a possible 17 times. Both of the times that Benjamin updated his mind map, he reported that he changed it after further reflection on his resource use, rather than to reflect changes to his use of resources. Brage also reported that his changes to his mind map did not correspond to changes to his resource use, apart from the addition of Maxima. Adrian and Anna only made a single change each, as they both added a resource for exam preparation. Only Andreas, and Christian made mind map changes that I consider changes to their documents.

Most changes to the data students filled into the app happened in the weeks leading up to exams, and were most likely tied to exam preparation being a class of situations that was activated. I would only consider Andreas' switch to lecture streams and the brief use of Maxima at University Beta to be changes to students' documents.

Theme 3.2: High degree of changes through adaption

Students schemes of utilization changed in response to new situations, whether or not they were caused by changes to the course context or more personal changes. Benjamin used the homework assistance in MyMathLabs when he felt behind on exercises. To him, this appeared to be a new class of situations, so he had to develop strategies for it.

B1 Used more… (0.5) the homework assistance we get in MyLabs. Er, used it more than I did at the start of the semester. Er, because, on the *homework* er… (1.5) *homework* exercises we have, there is the option to go through those examples and such. (Benjamin 3,3)

While never asked about it, some students compared their current use of resources to how they used resources during upper secondary school, which was a rather different context. This shed a light on developments that had taken place.

C3 In secondary I used to – after I had gone to class I used to go through the curriculum in the book, and I thought it worked well to (0.5) get an alternate explanation in addition to some repetition, while now I have started trying to do it first, so that I get more time for pure exercise solving after having been dealt the curriculum. (Christian 1,4)

Because the interviews with students from University Charlie happened late, they also had an opportunity to compare their use of resources in the new course to their use of resources throughout the previous semester. They were not specifically asked to do so, but Celine spontaneously addressed it:

C2 Now, this year, I have a math course where perhaps (1.0) I use student assistants more and such, I think. So, (1.5) it depends a bit on the courses, in a way. (Celine 3,3)

When asked what lead to the change, she said that it was because the current course provided fewer resources on their course page than the previous course. Thus, it can be interpreted as Celine making changes to her schemes of utilization because of a change to the context, which left her unable to employ certain aspects of her previous documents.

Brage’s addition of Maxima is the only change to a student’s mind maps that appears to be caused by changes to the course context. Similarly, Brage filled into the app that he used Maxima for a short period of time. Another change seen within app data is Andreas’ focus transitioning from lectures to lecture streaming. Since he said the change was relate to the type of exercises he had encountered recently, I consider it a change through adaption.

Combined with the stability of documents, this theme seems to suggest that students update their documents and reach new, stable documents within few weeks. For instance, it is likely that most of the students in the study needed to update their documents from upper secondary to university mathematics. However, by the time of the first interview, three to four weeks into the semester, they had already developed documents that appeared quite stable throughout the semester. Celine had only spent one week in the second semester course by the time she made the decision to rely more heavily on student assistants.

Theme 3.3: Low degree of changes within stable contexts

My assumption going into data collection, was that students would refine their documents a lot, simply through reflection on their usages. I thought increased experience with the use of various resources would lead to reflections on the effectiveness of their strategies. The extent of such changes within a stable context was much smaller than anticipated, although there were some instances. The four changes through reflection that are evident from interview data are Anna deciding to use the formula collection more throughout the year to get more familiar with its content; Casper deciding to take notes in a way that focused more on the essentials, rather than to write down everything; Celine describing her changes during exam preparations in a way that suggested she had updated the strategies after her first exam period and Christian, upon reflection, removing the compendium from his plans for the exam preparation during his second interview, deciding instead to focus on former exams.

A4 Er, will try to get better overview of what it says in it and such, so I will try to use it more (0.5) throughout the year. (Anna 3,6)

C3 Er… (3.0) summary slash compendium… (0.5) I guess I have not used – I do not think I will use it for exams either. So I will cross that off. (Christian 2,13, when updating his mind map)

The only other change through reflection that is evident from students' changes to their mind maps, is Andreas removing academic progression as a purpose for using the textbook.

Types of themes

If anything, the interview questions were biased in favor of changes to the students' use of resources, so the low degree of changes goes against my assumptions. I therefore consider the three themes in this category to be identified inductively. They are latent themes because I look at the degree and types of changes across the whole data set, while the students discuss individual changes and what caused them.

4.4.4 Didactical resource purposes

About the category

I derive the term ‘didactical resource purposes’ (DRPs) from two factors. First, the theme category is derived from statements on the form “I use resource X for Y”. So they can be considered a purpose that the students use resources for. On the other hand, they also correspond to phases of the students’ use of resources. Students tend to have at least one resource for each DRP. Didactical resource purposes can explain how the students organize their resource use by the order in which they use resources. In the documentational approach, the didactical component of a document concerns the organization of activity. Hence, the name didactical resource purposes. As mentioned at the start of the chapter, DRPs could be considered classes of situation that define documents, or they could be considered phases within a document. I prefer to think of them as the latter. Table 4.21 shows the number of statements from each student that the themes, subthemes and results within this category is identified based on.

Didactical resource purposes	**A1**	**A2**	**A3**	**A4**	**B1**	**B2**	**C1**	**C2**	**C3**	**Total**
4.1 Introduction	2	2	0	2	6	4	5	2	3	26
4.1.1 Emphasized resources used for introduction	Other numbers apply									
4.2 Practice	5	4	7	5	10	7	9	6	15	68
4.2.1 Variety of resources used for practice	Other numbers apply									
4.2.2 Exercises considered important	2	2	0	0	5	3	0	1	1	14
	Results from other themes also apply									
4.3 Evaluation	13	5	7	2	3	10	7	5	7	59
4.3.1 Three main strategies for checking answers	Other numbers apply									

4.3.2 Appreciation for every option in the assessment hypothetical	3	1	4	1	1	5	2	2	5	24
	Other numbers also apply									
4.3.a Some general evaluation	0	1	2	0	0	2	0	0	0	5
4.4 Explanation	0	4	1	2	9	13	7	4	7	47
4.4.1 Variety of resources used for explanation	Other numbers apply									
4.4.2 Appreciation for additional explanation	0	0	0	1	2	4	1	0	2	10
4.4.3 Search resources used to find utilization resources	0	0	0	0	1	5	2	3	3	14

Table 4.21: Breakdown of the number or statements from each student that each theme, subtheme and result within the category didactical resource purposes is based on. Subthemes are indented below the theme they relate to. Results are numerated with letters and indented if they apply specifically to one theme, representing one DRP. For some subthemes, other data will be presented later in the subsection.

Most of the statements that count towards table 4.21 are statements about specific strategies for what resources to use at various stages of the study processes. The exception is the assessment hypothetical, for which students were asked specifically about what form of assessment they would prefer from a program offering computer aided assessment, with the options of simple verification of correct answer, being told the correct answer, getting a hint or getting a detailed solution.

Description of didactical resource purposes

There are various phases to learning a new topic in mathematics. First, one needs to learn about the mathematical objects involved, the relationships between them, the terminology used and how said theory is applied in order to solve mathematical problems. Then, one needs to practice solving mathematical problems using the theory, both in order to become proficient at it and in order to solidify one's knowledge of the theory. Practice can also be used to evaluate one's understanding of the theory and one's capability to solve the problems. At any step of the process, one may find flaws in one's understanding of the theory, and may search for further explanations. Throughout the process of learning, students use resources for the four didactical resource purposes of introduction, practice, evaluation and explanation.

Theme 4.1: Introduction

When a mathematical topic is new to a student, they need to learn about basic objects, relationships and terms. Introduction to a topic can also describe what the topic is used for and why it is important. In this phase of the learning process, students use rather passive resources, involving either listening to or reading other people's reflections on the topic. This gives them a basic understanding of what the topic concerns, what is contained within the topic and what aspects are significant. It gives them a sufficient understanding to formulate good questions to ask in order to further their understanding. Some of the statements that inspired this theme specifically called it introduction (for instance, Benjamin in the quote below), while others referred to resource used for theory (see Amalie quote below), or simply, the resources the student said they 'went to first'.

A2 I mostly use the textbook to read the theory of the material. (Amalie 1,3)

B1 The first videos are always (1.0) made for introduction to (1.0) topics and, like, to see 'what is this thing?' and… (1.0) usually it also is… nicely put into a system where you can see (1.0) what it is used for and… (1.5) so on (Benjamin 3,8)

Only one of the mind maps were structured based on the situations in which the student used various resources. In it, Casper had an item for new curriculum, and linked the resources textbook, website and overview lecture to it. The following subtheme regards the types of resources used for introduction

Subtheme 4.1.1: Emphasized resources used for introduction

Students almost exclusively use emphasized resources for introduction to a topic. This may be because emphasized resources not only help them understand the mathematical topic on its own, but also what significance various aspects of the topic has within the course they are taking. Table 4.22 marks in grey which resources various students in the project mentioned using for purposes that I labelled as introduction.

Themes	**A1**	**A2**	**A3**	**A4**	**B1**	**B2**	**C1**	**C2**	**C3**	**Total**
Lectures/lecture notes										6
Textbook										5
Video lectures										2
Math wiki										2
Internet										1
Khan Academy										1

Table 4.22: Which students mentioned using what resources for introduction (marked in grey). Internet and Khan Academy were the only non-emphasized resources mentioned. Student A3 did not mention using resources for introduction.

The non-emphasized resources within the table are internet and Khan Academy. As table 4.22 shows, all the students who mentioned the resources they used for introduction, had at least one emphasized resource that they used for introduction and only two used a non-emphasized resource as well. Casper indicated the same resources in his mind map linked to “new curriculum” as he mentioned during the interviews. Several of the students also specified that they took notes when they mentioned attending the lectures. For instance, Celine described the resources she used first for a new topic as follows:

> C2 Well, the textbook I guess may be what I go to first, right. So it (1.0) er, try to read in it, at least. [laughs] But it is a bit heavy to look up with, so (0.5) it becomes a bit less. And then the lecture that one attends (1.0) takes notes. (Celine 1,1)

Theme 4.2: Practice

Working mathematically is a big part of students’ learning process, whether it is to solve exercises given in a textbook or to explore features of mathematical objects through various resources. Based on the students within the project, they mostly work on exercises, but Benjamin additionally put interactive as a category in his mind map, with simulations as a resource. He reported multiple exploratory strategies when he discussed why he added “interactive” and “simulations” as items in his mind map during the third interview:

B1 That is to draw a graph and then you can, like, drag on those sliders or something, then see how things change when the values change and such. Simulations for shapes and such, how they change with – over time and bla bla bla, so… That is what I mean by those, and calculator, for me it is like (1.0) well, it is just to sit with a calculator and test different (0.5) theories and just… (1.0) Like… With that item I mean things that you can (1.5) what to say? (1.0) change and do something with on your own, right (Benjamin 3,1)

Casper specifically used a Norwegian term for practice as a type of situation in his mind map. Linked to it, he had resources he used for it, with arrows to indicate the order in which he used them. He went to the interactive lecture first, used Wolfram Alpha while he worked on exercises and attended the plenary session afterward. He used pencil and paper at every step of the way. Notably, as witnessed in table 4.23, he did not mention all of those resources during the interviews. From the students who included purpose items in their mind maps, they communicated their schemes in various ways. Adrian wrote that he uses the textbook to find exercises and the calculator for calculations. Andreas wrote that he uses fellow students to solve problems in a group. Anna uses fellow students to work with and compare methods and answers. Benjamin uses lectures to get demonstration of exercises through examples. Other students also included resources in their mind map that they later reported using for practice during the interview section.

As shown in the mind maps, resources for practice are used for multiple sub-purposes. One may need resources to find tasks and resources to solve them. While one may also use resources to check one's work, that is included in the DRP evaluation instead. Thus, each student may use a variety of resources.

Theme 4.2.1: Variety of resources used for practice

Students use many different resources to find or solve exercises. The students who participated in the project mentioned a total of 17 resources used for practice. The only resource that more than half the students reported using is fellow students, which all the students reported using. On average, the students used 3.67 resources each for the purpose of practice. Table 4.23 shows which resources were mentioned by which students as something they use for exercises or exploration during their interviews. Note that app data and mind map data do not factor into the table. Based on app data A4, C1 and C2 used calculator, which presumably was for exercises. It also seems likely that when app data showed everyone from universities Alpha and Charlie using pencil and paper, and everyone from University Charlie using Wolfram Alpha, they used them for exercises. In the case of Casper, he indicated clearly in his mind map that he used pencil and paper, Wolfram Alpha and plenary sessions for practice, yet he did not mention using them for practice during the interviews.

Resource	**A1**	**A2**	**A3**	**A4**	**B1**	**B2**	**C1**	**C2**	**C3**	**Total**
Pencil & paper										2
Calculator										4
Fellow students										9
Parent										1
Textbook										2
Wolfram Alpha										1
Simulations										1
MyMathLabs exercises										2
MyMathLabs examples										1
Interactive lecture										2
Math lab										2
Videos										1
Google										1
Math wiki										1
Maple TA										1
Plenary session										1
Windows & marker										1

Table 4.23: Which students reported using what resources for exploration or exercises (marked in grey). This table is based on interview data, and does not include resources for practice that were only mentioned in the mind map or can be inferred from Studert app data.

We see that there is a large variety of resources used for practice. Social resources, digital resources and material resources are all represented, and there are both emphasized and non-emphasized resources. Following are some examples of statements that indicated resources used for practice:

A2 Others in class to cooperate (0.5) on the exercises. Ehm… then I get help from home if I need help on how to solve them (Amalie 1,2)

B2 Ehm, when we solve – we solve exercises as homework, like, in MathLab – or MyMathLabs. Er… and there I use very much the function with t… – for examples on how the exercise should be solved. (Brage 1,1)

C3 Well, first and foremost I use the most obvious resources. Pencil and paper and calculator to take notes and to solve exercises. (Christian 1,1)

The next subtheme concerns students' attitude towards working on exercises.

Subtheme 4.2.2: Importance of exercises

Students tend to see exercises as very important, if not the most important part of their studies of mathematics. When I asked open questions about how they used resources to learn mathematics, they often mentioned the resources they used for exercises very early. The excerpts from subtheme 4.2.1 (page 159) is an example of this. Students also explicitly talked about considering exercises important, either for their own learning process or in general:

A2 That is usually what math is about, right, exercises. (Amalie 1,3)

A2 I find it easier to learn if I calculate many exercises, than if I just sit and read theory. (Amalie 1,8)

C3 The textbook I think is quite nice, and then I think doing exercises is essential. That stems from math being a repetition course and if you do not do exercises you are *fucked* at exams. And you will not learn either, if you do not do exercises, so… yeah. (Christian 1,6)

Even when they discussed resources used for introduction, Amalie and Brage tended to phrase it in a way that suggested that they mainly focused on learning how to solve exercises:

A2 Like, the textbook to (1.5) find… (1.0) like (0.5) the curriculum we are covering and how I am to do the exercises and such. Internet too to find out (0.5) how I solve exercises as well, for inst… - instance for the, and… pretty much like the book. (Amalie 1,2)

B2 If it is a new topic, right, then I first decide to look through the video lectures (0.5) so that I, like, understand how to solve them and such (Brage 1,2)

It is also worth pointing out that solving problems from previous exam sets, which is a form of practice, is a large part of students' strategies for exam preparation (see subtheme 1.1.1, page 130). It may be that the exams are a large part of why student consider exercises important to themselves or more generally consider exercises to be an important part of mathematics as a cultural endeavor.

Theme 4.3: Evaluation

Through the course of their learning process, students need to get feedback or use self-evaluation to evaluate their work and understanding. The most common form of evaluation comes from students' efforts to check whether they have solved exercises correctly and potentially comparing their answer and solution method to correct answers or suggested solutions. They may also use social resources to help them locate errors. For students, this form of evaluation may simply help them improve their skills tied to solving exercises, or it may help them evaluate their understanding of the theory that relates to the exercises. There are two subthemes to this theme. One is that there are three main types of strategies for checking answers, while the other concerns the assessment hypothetical, and that each of the four options within it are appreciated by a good number of students. A few statements by students regarding more generally evaluating themselves are included as a result.

Subtheme 4.3.1: Three main strategies for checking answers

Table 4.24 shows the resources that various students mentioned using to check their answers. Also included is a breakdown based on the following three categories: Digital calculation tools (GeoGebra, Wolfram Alpha and calculator); social resources (fellow students, lecturer, parent, plenary session and student assistants) and the source of the exercises (textbook, MyMathLabs). Note that pencil and paper is the only resource in the table that is not coded as belonging to either of the three types of strategies. The categories relate to the three main strategies for checking answers.

Resources	A1	A2	A3	A4	B1	B2	C1	C2	C3	Total
GeoGebra										2
Wolfram Alpha										4
Calculator										1
Pencil and paper										1
Fellow students										3
Lecturer										4
Parent										1
Plenary session										2
Student assistants										2
Textbook										3
MyMathLabs										2
Digital calculation tools										5
Social resources										7
The source of the exercises										5

Table 4.24: Which students mentioned using what resources to check their answers when working on exercises (marked in grey). Below the bold horizontal line it is marked which students used at least one digital calculation tool, at least one social resource or at least one resource that was additionally the source of the exercises.

From table 4.24, we can see that given the typology of three resource categories, each corresponding to a strategy for checking answers, each strategy was used by more than half the students. Seven students used at least two of the types of strategies, while Celine used all three.

The digital calculation strategy involves a student solving an exercise with pencil and paper methods. They then solve it using digital calculation tools to arrive at the correct answer or an approximation thereof. The purpose of the second calculation is merely to obtain the correct answer, in order to check the work they did with pencil and paper. For instance, Andreas' mind map includes the purpose of controlling his answers linked to automated calculation with Wolfram Alpha. Sometimes the students go on to use the digital tools to try to locate what part of their pencil and paper solution is incorrect. While the students do not explicitly address it, this strategy indicates that the students can solve the exercises more reliably with the digital tools, but consider it more important to learn how to solve them by pencil and paper.

C1 If it – often if there are graphs that I am unsure about (1.0) or (1.0) things I want to check how a graph looked like or such, then I use it to draw the graph. Then I can see approximately where the answer will be. (Casper 2,7)

C3 Last semester we had (0.5) the volume of (1.0) that and that rotational bodies I was about to say, (1.5) and (0.5) then, then you cannot plug it into the calculator, but in Wolfram Alpha it is possible. If I had gotten an answer that did not work with the answers, I would type it in there to check – or to sort of figure out where the error lies (1.0) by condensing (0.5) the expression. (Christian 3,10)

In addition to often being used while solving an exercise, social resources are often employed by students after arriving at an answer. In particular, social resources are used in order to locate the error(s) and evaluate the method used to arrive at the answer. Some indications of this are evident in the students' mind maps. Adrian's mind map indicates that fellow students can both help him check the answer and be an extra pair of eyes to look for minor mistakes. Anna's mind map includes using fellow students to compare methods and answers. There is even more data regarding students' social strategies for checking their answers within the interview data. For instance, Amalie and Celine said the following about asking her mother and using the video of the plenary session, respectively:

A2 And then I would test myself on how I did it and put in (0.5) those things, and then she would (1.5) have seen if it was (0.5) correct or if I – what I had to change and such. (Amalie 1,20)

C2 We have a plenary session where a person goes through exercises, and I think I learn more if I – because videos are put up afterward, so then, like, I do an exercise and then I see him do that exercise, so I make, like, my own thing (Celine 1,6)

The third strategy involves using the source of the exercises, which in the case of the three courses in question are either the textbook or MyMathLabs. Specifically, the textbook is used because there is a section with the correct answers in the back of the book. MyMathLabs can both give feedback on whether the answer a student enters is correct, and gave detailed solutions for some exercises, which Brage in particular uses and appreciates, as he mentioned both in his mind map and during the interviews:

B2 Er, it is very important to me, or I emphasize a lot on MyMathLabs, right (1.0) and the step by step solutions. And the part where one gets feedback on wrong answers. (Brage 2,11)

Subtheme 4.3.2: Appreciation for every option in the assessment hypothetical

As mentioned in subsection 3.5.4 (page 72), the assessment hypothetical was inspired by a statement from Anna. She said:

A4 The answers to the exercises I just use to check if I got the right answer, or if (1.0) if I do not get it and I just sit by myself… then I look at it. (Anna 1,17)

The intent behind the hypothetical was to check whether students indeed used the answer to a given question in order to check their work, rather than to guide their solution. It is my impression that several lecturers assume that students use the answers to guide their solution, and that they learn less as a result. In fact, Adrian voiced similar concerns in his response to the hypothetical.

A1 if you… just… look in the back of the book first, then of course it – you are the only one you are cheating, and it is… (1.0) shows, of course, on the exams if you have (1.5) if you have just looked at the answer and thought 'yes, that answer looks alright', then (1.0) you have, like, skipped the part where you solve the exercise (Adrian 3, 10)

When designing the hypothetical, I decided to include hint and detailed solution as options and ask how they would use all the options, rather than just which options they would use. As a reminder, the question was based around a hypothetical program with computer aided assessment and the four options were to ask the program:

A. To tell you whether your answer was correct or incorrect
B. For the correct answer
C. For a hint
D. For a detailed solution of the problem

The options that students indicated that they would use are marked as grey in table 4.25.

<table>
<tr><th>Option</th><th>A1</th><th>A2</th><th>A3</th><th>A4</th><th>B1</th><th>B2</th><th>C1</th><th>C2</th><th>C3</th><th>Total</th></tr>
<tr><td>A. Correct/incorrect</td><td style="background:#c0c0c0"></td><td style="background:#c0c0c0"></td><td style="background:#c0c0c0"></td><td style="background:#c0c0c0"></td><td style="background:#c0c0c0"></td><td></td><td></td><td></td><td></td><td>5</td></tr>
<tr><td>B. Right answer</td><td style="background:#c0c0c0"></td><td style="background:#c0c0c0"></td><td style="background:#c0c0c0"></td><td></td><td></td><td></td><td style="background:#c0c0c0"></td><td style="background:#c0c0c0"></td><td></td><td>5</td></tr>
<tr><td>C. Hint</td><td style="background:#c0c0c0"></td><td></td><td style="background:#c0c0c0"></td><td></td><td></td><td></td><td></td><td style="background:#c0c0c0"></td><td style="background:#c0c0c0"></td><td>4</td></tr>
<tr><td>D. Detailed solution</td><td style="background:#c0c0c0"></td><td style="background:#c0c0c0"></td><td style="background:#c0c0c0"></td><td style="background:#c0c0c0"></td><td></td><td style="background:#c0c0c0"></td><td style="background:#c0c0c0"></td><td style="background:#c0c0c0"></td><td style="background:#c0c0c0"></td><td>8</td></tr>
</table>

Table 4.25: Which options in the assessment hypothetical that each student said they would use (marked in grey). Students' answers vary, but each option would be used by several students and most students would use more than one option.

As shown in table 4.25, students' indication of which options they would use varied, but for each option, at least four students said they would use it. It should be mentioned that students from University Beta related the question to their experiences with MyMathLabs, which they thought gave rather poor hints (see quote from Benjamin below). Students from University Charlie related the question to their experiences with Maple TA, which included difficulty with the verification of correct answers due to the students finding it difficult to answer with the correct syntax (see quote from Christian below). It is possible that the totals for options A and C would be higher if it was not for these issues.

B1 You get an exercise, and then (1.5) you get… (1.5) er… (0.5) you insert and answer, then you either get right or wrong. If it is wrong, then it is like … (1.0) there is a hint, usually, right, that you have to use a formula or something, but it is like – that is the only feedback, so if you have used that formula, it does not help very much (Benjamin 3,11)

C3 Er… standard… (0.5) right wrong type problems (1.0) I actually hate to a high degree. We have it at the moment, and it is awful, because… Sometimes I get it wrong and then it is, either, for instance (0.5) the syntax I have entered is wrong, or it is like… well, typed a number wrong or it is, that I have done a slouch error in the book, or something. I do not know what it is, so I end up having to do the exercise over again. Often multiple times. Hate it. (Christian 3,8)

Table 4.26 shows the orders in which each student would use the various options, based on their answer. Most follow the order of the options in the phrasing of the question (from least to most information), with the exception being Celine, who would use hints before the correct answer and Andreas who did not indicate an order. Andreas interpreted the hypothetical as how he would want an instructor to implement it in their teaching. He said he would want the instructor to restrict the order to which students got access to the various options.

A3 Potentially (1.5) er, start somewhere and then give more and more access. You start by first getting to know if it is right or wrong, and then (1.0) you increase – you can ask for a hint, and then you can ask for an answer, then you can ask for detailed, for instance. (Andreas 3,8)

While his answer indicated a specific order of use, it was not included in table 4.26 since he was not specifically indicating the order in which he himself would use the four options.

Student	First	Second	Third	Fourth	Fifth
A1 Adrian	A	2nd attempt	B	C	D
A2 Amalie	A	B	D		
A3 Andreas	Different interpretation of the question				
A4 Anna	A	2nd attempt	D		
B1 Benjamin	A				
B2 Brage	D				
C1 Casper	B	D			
C2 Celine	C	B	D		
C3 Christian	C	D			

Table 4.26: The order in which the students said they would use the various options in the hypothetical, moving on to the next option when they were unable to solve an exercise. Adrian and Anna also mentioned specifically that they would make a second attempt if they were incorrect, rather than go to the next option right away.

The statement by Anna that inspired the hypothetical mostly appears representative for the attitude among students at University Alpha. The other two who interpreted the question the same way, indicated that they would start with feedback on whether their answer was correct before moving on to a second attempt or options for more information. For the other universities, the strategies are more varied. Apart from Benjamin, everyone appears to appreciate the option to get a detailed solution, and put it as option they would use last.

A1 I think that (2.0) what I would have done, it would be to (0.5) use the first alternative, right wrong, until I arrived at something that was wrong. If it was wrong (1.0) I would have done the exercise again, and if it was still wrong (1.0) I would have (1.0) tried right answer. […] and then I think that if I still had not understood the hint then I would go to the detailed solution. (Adrian 3,10)

B1 For me it is really – am mostly concerned with if it is actu… – right or wrong, so in that sense it is… (5.5) In that sense it is – would like to have [laughs] actually how it is in MyLabs, just that you get more attempt on wrong answers (Benjamin 3,12)

While the majority of the students talked about checking their answers, a result tied to the DRP evaluation, is that some students talked about evaluating themselves and their learning process more generally.

Result 4.3.a: Some general evaluation

While the students in the projects more commonly evaluated their answers and solution methods for specific exercises, there was evidence to suggest that some students were concerned with evaluating more generally their approach to learning mathematics. Andreas, for instance, mentioned that lectures are a good way to check his progression compared to what is expected in the course. He also talked more general about self-evaluation:

A3 I have – I want to control what I do, that the work I do is correct and that (1.0) I do not learn mistakes (1.0) or adopt poor habits. Er (0.5) so if I have the option to evaluate myself, I will. (Andreas 3,7)

Brage did not talk self-evaluation in so specific terms, but when asked how he had experienced participating in the project, he said that he liked to use the weekly statistics in the Studert app to check how much he worked on the mathematics course compared to the lecturer's recommendation.

B2 And then it was pretty nice to look at the weekly statistics, we could see how many hours we had worked so one can get a bit… It a bit visually for yourself, how much you worked on the course. Because it is… (1.0) The teacher has said that we are to – it is recommended to work seven hours a week on math, but…

(0.5) it is a bit difficult to reach it, while if you – unless it is a week with tests and such. [Inaudible]. So it is a bit nice to see, right, how much you have actually worked. (Brage 3,12)

As one can read in subsection 4.2.6 (page 110 and onwards), Brage recorded a total of 57 hours spent on the course across eight weeks, resulting in an average of a little over seven hours a week.

Theme 4.4: Explanation

Whether students find that they do not understand something after the introduction to a topic, or later find that they need certain information, students have resources that they use resources for explanation.

A2 I had that when I ha… – attended secondary, so then I go back to look at the (0.5) exercises I did there (1.0) er… in addition to working with people in class to figure out how we should (1.0) calculate it. (Amalie 1,5)

Explanation is here used to encompass any part of the learning process after introduction that involves the student searching for information on the topic in general, rather than a specific exercise. It can include general information that they need for a specific exercises. It encompasses a wide range of actions. For instance, it both includes looking up specific formulas and rereading chapters in the textbook for repetition. Compared to introduction, students' use of resources for explanation is a more active process, where they know what aspects of the topic they need to check or want to deepen their understanding of. As such, their strategies often include skipping over a lot of the information that each resource provides:

B1 Has to be the video things, then (2.0) Er… (2.5) Like, er… (2.0) uses them to… (2.0) er… (1.0) well, skip to where I want to… see from, for instance, if I want a (0.5) calculation that I take (2.0) Faster than… what is in the video, then I just skip past it, and if there are things I need multiple times, then like (0.5) I see it several times and take notes during it and… (1.5) then (0.5) repeat er… (2.0) exactly that small part of the video again and again, and then I might skip past the rest. (Benjamin 1,5)

Explanation is also represented within certain mind maps. Casper wrote down repetition as a type of situation, while Anna had it labelled as a purpose for lectures. Adrian looked up formulas in the textbook and occasionally used

Google for formulas and rules. Andreas had academic depth as a purpose for the textbook and the lecturer, and I interpret his use of the term to be included within explanation. Brage also had elaboration as a purpose linked to the textbook.

Within the Studert app, there was no way to indicate that a resource was used for explanation, so none of the app data had the potential to support or contradict this theme.

I have identified three subthemes for this theme. The first is that a variety of resources are used for explanation. The second is that students appreciate additional explanation and the third is that when they used search resources, the resources that they found are simply utilized.

Subtheme 4.4.1: Variety of resources used for explanation

Since explanation can be used for learning multiple aspects of a mathematical topic, from specific to general aspects, most students have multiple resources for explanation. Some are resources that the students use as a plan B if they are unable to accomplish their goals with the resources they first use for explanation. Table 4.27 shows which resources were mentioned by which students. A total of 13 resources were mentioned. On average, the students used 3.11 resources for explanation (3.38 if we exclude Adrian who did not mention explanation).

Resources	**A1**	**A2**	**A3**	**A4**	**B1**	**B2**	**C1**	**C2**	**C3**	**Total**
Textbook										6
Old math books										1
Fellow students										2
Parents										1
Lecturer										2
Lectures										2
Lecture notes										1
Video lectures										3
Google										3
YouTube										4
Internet										1
Khan Academy										1
Math wiki										1

Table 4.27: Which students reported using what resources for explanation (marked in grey). Most students used multiple resources, but Andreas only used one and Adrian did not use any.

The resources mentioned in statements related to explanation varied in terms of whether they were digital (see, for instance, quote by Benjamin below), social or material resources and in terms of whether they were emphasized or not. However, one notable trend is that students from University Alpha only used emphasized resources and social resources.

A3 I usually go to… (2.0) the teacher if I am stuck. If fellow students cannot help, er… (2.5). Usually I get a very detailed (1.0) calculation, very detailed *fremgangsmåte** and explained very well. (Andreas 1,2)

* The Norwegian word "fremgangsmåte" may refer either to a solution method or to a more general approach to a task.

B1 Er, the videos are the simplest. And to – to get an explanation to things, to – to get it shown how to do it. That is preferable. (Benjamin 1,3)

Looking across the resources used, a reasonable typology for the most common resources might be to divide them into textbooks, social resources, video resources and search resources. 'Textbooks' is only represented by the resource textbook; 'social resources' is represented by parent, fellow students, lecturer and lectures; 'video resources' is represented by video lectures, YouTube and Khan Academy and 'search resources' is represented by Google, YouTube and Internet. Math Wiki, old math books and lecture notes do not fit within the typology. Table 4.28 shows how many students used at least one resource from each of these types.

Resources	**A1**	**A2**	**A3**	**A4**	**B1**	**B2**	**C1**	**C2**	**C3**	**Total**
Textbooks										6
Social resources										4
Video resources										4
Search resources										4

Table 4.28: Type of resource for explanation and which students used at least one

resource for each type (marked in grey). The rightmost column shows the total number of students who mentioned a resource from each type.

We see that most of the students used explanation resources of multiple types. The following subtheme may describe some of the reason why that is.

Subtheme 4.4.2: Appreciation for additional explanation

People make their own interpretations on everything they experience and mathematics is no exception. Because of this, one might develop one's understanding by getting information from multiple sources. Six of the students who participated expressed wanting multiple perspectives. They mentioned using certain resources specifically to get an additional take on the mathematical topic at hand. They used terms such as resources from different people containing different perspectives or looking at the topic from different angles. Textbook, lectures and video resources were frequently mentioned. See for instance the following quotes from Anna, Brage and Casper:

A4 And then I use the math book to – or the textbook, to (0.5) do exercises and look at (1.0) different ways to solve exercises that are different from the lectures. (Anna 1,1)

B2 and I might also look at video lectures on YouTube from other people, to get a – like a (1.0) Er, a somewhat different angle on the problem, and solutions as well, for instance (Brage 1,3)

C3 Lectures I could do without, but it is ideal to get two different viewpoints on the same thing, or two different explanations. (Christian 1,6)

Note that it was difficult to decide whether to include this subtheme into introduction or explanation. Most of the students used similar resources to the introduction DRP, and the extent to which the students indicated using the additional resource during introduction or afterwards varied. In the end, I decided to make it a subtheme of explanation based on the name.

Subtheme 4.4.3: Search resources used to find utilization resources

In theory, students can use Google and YouTube's search functionalities to find web pages or individual YouTube channels or videos that they then start using regularly and one can say that these resources are incorporated into the students' resource systems. However, only one statement from Brage, and no statement from any other student in the project, suggested that this was the case. When asked whether he used resources more if he liked them, Brage said:

B2 Yes… yeah, well, of course it is (0.5) like, once you find a (1.0) er… good resource or web page for instance, then… (0.5) you often come back to it. (Brage 1,5)

He did not give any example or say how he would locate a useful web page again (for instance, bookmarking, remembering the search words, etc.). Generally, the students made statements that were unclear, and it is my interpretation that it is more likely that the resources they found were simply utilized. This included the rest of the statements by Brage on searching online.

B2 Well, internet is what (0.5) is usually the place where I search if I… (1.5) to find a quick (1.5) er… [Writes] find a quick solution to one problem or another if there is something or other I wonder about or something (Brage 2,11)

The idea that resources found through search resources are utilized is also supported by looking at how students answered the question about how they discovered the various resources they used. None of them said that they found any of the resources they used through a search resource.

Type of themes

All the themes within this category are inductive, latent themes. Apart from the statements related to the hypothetical, students brought up what they used resources for in open questions about use of resources, discovery of resources and changes to their use of resources. What resources students used in different stages of their learning process was not a topic I had focused on when I designed the interview questions, and was something the students spontaneously chose to focus on. The terminology of didactical resource purposes is introduced by me, and while some students used the terms introduction, practice or explanation, I also included within those DRPs students who instead mentioned 'theory', 'exercises' or 'repetition'. Subthemes 4.1.1 (page 157), 4.2.1 (page 159), 4.3.1 (page 162) and 4.4.1 (page 170) also look at the resources mentioned from all the students. No individual student made a statement to the effect that students used a variety of resources for explanation. The subtheme about additional explanation is more semantic than the rest. However, I still count it as more latent than semantic, because most of the statements were specific about using a certain resource for additional explanation, while the theme is more generally about students appreciating getting an additional explanation.

4.4.5 Resource decisions

About the category

The category ‘resource decisions’ is about what aspects students consider when they decide what resources to use. One of the interview questions concerns how they decide what resources to use in general. Based on a working hypothesis, I also asked students specifically whether preference influences their decision. Students mostly answered that preference influence their decision, but that they primarily pick the resources that suit the task at hand. While this category is named resource decisions, two other categories also relate to resource decisions. ‘Resource discovery’ details how students arrive at the pool of resources that they consider when they make decisions, while ‘quality criteria’ sheds some light on why students prefer certain resources and why they find certain resources more suitable than others. Table 4.29 shows the number of statements from each student that the themes, subthemes and results within this category is identified based on. The statements that count towards goal-based decisions are from students saying that they made decisions based on how suitable a resource was for a task (for instance the exercises they worked on) and statements about what resources students go to first for certain goals and which they went to if necessary. There is a large overlap between statements related to goal-based decision and statements related to experienced difficulty being a class of situations. Statements that count towards resource based decisions include statements from students saying that they made decisions based on preference; statements where they mentioned using a certain resource because they preferred it; statements where they mentioned a resource they did not use because they did not prefer it and statements about certain resources that they liked more than certain other resources.

Resource decisions	**A1**	**A2**	**A3**	**A4**	**B1**	**B2**	**C1**	**C2**	**C3**	**Total**
5.1 Primarily goal-based decisions	5	4	4	2	1	8	4	2	5	35

5.1.1 Emphasized resources used before non-emphasized resources	Other numbers apply									
5.1.a Fellow students used before the lecturer	0	0	2	0	0	1	0	0	1	4
5.2 Decisions are partially preference-based	5	2	5	0	3	3	3	3	4	28
5.2.1 Fellow students are generally appreciated	Other numbers apply									
5.2.2 Not much appreciation for the textbook	Other numbers apply									
5.2.a Unfamiliar digital resources not appreciated	0	0	0	0	1	0	1	0	1	3

Table 4.29: Breakdown of the number or statements from each student that each theme, subtheme and result within the category resource decisions is based on. Subthemes are indented below the theme they relate to. Results are numerated with letters and indented if they apply specifically to one theme, representing one DRP. For some subthemes, other data will be presented later in the subsection.

Description of resource decisions

While one can argue about the degree to which students' choices are bound by the socio-cultural context, students at university tend to be given more freedom to choose when and how to work than students at lower levels of education. While the lecturer and course organizers may provide certain resources and recommend others, students make the final decision on what resources to use. In general, students make their decisions based on what resources they anticipate will help them achieve their goals, while personal preference is a secondary concern, which comes into play when there are multiple resources that the student considers suitable. When students discuss using resources to achieve their goals, they tend to describe what resources they use first and what resources they use if necessary.

Theme 5.1: Primarily goal-based decisions

Students set goals in their pursuit of learning mathematics. They primarily consider the task at hand and what resources they consider suitable for said task when they decide what resources to use in a given situation.

A1 Well, it is (0.5) how (0.5) well, how suited it is for the purpose, how available it is… ehm… (1.0) And then, of course, to an extent how comfortable I am with it. (Adrian 1,7)

A2 It depend a bit on which exercise – or how the exercise is. (Amalie 1,4)

Students have certain resources that they use first for a given goal and certain resource that they may use if they do not initially achieve their goals, for instance Anna goes to online resources if necessary:

A4 If (1.0) there is something I do not quite understand, even though I have… through the notes and the book, it might happen that I (0.5) search online for an explanation, right. And such. (Anna 1,3)

Table 4.30 shows how many students mentioned each resource or resource category as belonging to ‘plan A’ for at least one of their goal-based strategies, and how many students mentioned each resource or resource category as belonging to ‘plan B’ for at least one strategy. This is relevant for the subtheme and result tied to this theme. I also indicate whether I consider each resource or resource category to be emphasized within the course(s) that the student(s) who mentioned it were taking. For fellow students and lecturer it is unclear whether they are emphasized.

Resource/resource category	**Emphasized**	**Plan A**	**Plan B**
Textbook	Yes	7	2
Lecture notes	Yes	3	0
Lectures	Yes	2	0

Video lectures	Yes	2	2
Pencil & paper	Yes	2	0
Calculator	Yes	1	1
Exercises	Yes	1	0
Math wiki	Yes	1	0
Emphasized resources in general	Yes	1	0
“What is at hand”	Yes	1	0
MyMathLabs exercises	Yes	1	0
MyMathLabs examples	Yes	1	1
MyMathLabs textbook	Yes	0	1
Rottman’s formula collection	Yes	0	1
Fellow students	Unclear	3	2
Lecturer	Unclear	0	4
Old math books	No	1	1
Wolfram Alpha	No	1	2
A hypothetical formula collection, specific for the course	No	1	0
Calculator’s polynomial feature	No	0	1
CAS tools	No	0	1
“Other resources”	No	0	1
Khan Academy	No	0	1
Google	No	0	3
YouTube	No	0	3
Internet	No	0	4

Table 4.30: Resources used and the number of students who mentioned each resource or resource category belonging to plan A or plan B within at least one of their strategies tied to goal-based decisions. The second column covers whether a resource was emphasized within the course(s) that the student(s) who mentioned it attended or not.

There is one subtheme and one result for this theme. The subtheme is that emphasized resources usually belong to plan A, while non-emphasized resources are used as plan B. The result is that students reported that they used fellow students as plan A and the lecturer as plan B.

Subtheme 5.1.1: Emphasized resources used before non-emphasized resources

When students make goal-based decisions, they generally decide to go to emphasized resources first, while they have non-emphasized resources as back-up strategies if they do not achieve their goals with the resources they initially tried. Presumably, they consider resources emphasized within the course to be more suitable for tasks within the course and more likely to help them achieve their goals due to the significance of those resources within the context of the course. Brage not only exemplified this, but explicitly addressed it:

> B2 If it does no… I feel that (0.5) it – the resources that the course emphasizes are not sufficient, that I do not quite understand (0.5) how to solve an exercise, or do not get it, then (0.5) I usually end up searching on Google or something, at least at first. (Brage 1,4)

Adding up the numbers for the emphasizes and non-emphasized resources in table 34, we get table 35, which shows the predominance of emphasized resources used as plan A and non-emphasized resources used as plan B.

	Emphasized resources	**Non-emphasized resources**
Plan A	23	3
Plan B	8	17

Table 4.31: The number of times emphasized and non-emphasized resources or resource categories were mentioned as belonging to plan A or plan B within students' strategies tied to goal-based decisions (when the same student mentioning the same resource as part of the same type of plan an additional time is not counted).

Result 5.1.a: Fellow students used before the lecturer

All the students who both used the lecturer and fellow students on occasion always went to fellow students for help first. Andreas, Brage and Christian made statements that exclusively addressed those two resources, and all put fellow students as what they went to first (for instance, see Christian quote below).

Andreas made two statements to that effect. Andreas said the reason was that the "mental bar" for going to the lecturer was higher than for going to fellow students (see quote below). This may mean that students are less comfortable asking the lecturers due to the asymmetrical power dynamic.

A3 Yes, and then there is that mental bar, it is easier to ask students than to go to the teachers. Every time it… (1.5) you run into a hurdle. (Andreas 3,4)

C3 Then I talked to my friends in the break about what we had gone through and then I did not get it, right, so I talked to the lecturer about it, and then… Ehm, yeah. Yeah, I guess that's it. (Christian 1,3)

Theme 5.2: Decisions are partially preference-based

While students tend to focus on which resources help them achieve their goals, there can be more than one resource with the potential to do so. In that case, they choose based on preference. Casper answered the following when asked whether there was a connection between resource he liked and resources he used.

C1 It is quite strong, right. It… If I can find something that likes, that works, which usually is possible to find, then… I rather use that than something I do not like. (Casper 1,9)

However, the students in the project were not unanimous in this view. When asked about whether preference influenced their decisions, most students said yes, and stressed that what resources were suitable for the task at hand was equally or more important. Anna, however, said that preference did not factor into her decisions.

A4 I guess I use (1.0) all of them anyways (Anna 1,10)

Spontaneously or in response to a question about it during the first interview, students mentioned resources they used (or would have liked to use) or did not use because they liked or disliked them. Often their statements took the form of mentioning resources that they preferred over other resources. Table 4.32 shows how many student said at least once that they liked or disliked a certain resource or category of resources. I also indicate whether I consider each resource or resource category to be emphasized within the course(s) that the student(s) who mentioned it attended. For fellow students and lecturer, it is unclear whether they are emphasized or not within any of the courses.

Resource/resource category	Emphasized	Liked or preferred over other resource	Disliked or not preferred
Exercises	Yes	2	0
Lectures	Yes	2	0
Video lectures	Yes	2	1
Pencil & paper	Yes	1	0
Calculator	Yes	1	0
MyMathLabs	Yes	1	0
Textbook	Yes	1	4
Maxima	Yes	0	1
Maple TA	Yes	0	1
Fellow students	Unclear	4	0
Social resources	Unclear	1	0
Text resources	Unclear	0	1
Lecturer	Unclear	0	1
Matlab	No	2	0
Writing on windows	No	1	0
Excel	No	0	1
Digital resources	No	0	1
Internet	No	0	1
Khan Academy	No	0	1

Table 4.32: The number of students who at least once mentioned liking or disliking each resource or resource category. The second column covers whether a resource was emphasized within the course(s) of the student(s) who mentioned it or not.

Two subthemes and one result relate to this theme and specifically to the results presented in table 4.32. The first subtheme is that students generally appreciate the emphasized resources, as well as working with fellow students. The second is the exception that the textbook is not highly appreciated, while the result is that students do not appreciate digital resources that are new and unfamiliar to them.

Subtheme 5.2.1: Fellow students and emphasized resources are generally appreciated

Students only addressed some examples of resources they liked and disliked, and did not give an opinion on every resource they used. Hence, the total sum of statements represented in table 4.32 is rather low. It is likely that they mentioned resources that they had a particularly strong opinion on. The resource that most students mentioned liking was fellow students. Assuming that it is included in the category "social resources", five of the nine students like it. For instance, Adrian and Amalie said:

A1 Of course, when it comes to human resources, then er… I work along others not just because things get easier, but because it is pleasant, because it is social and such and (0.5) strengthens the social… (Adrian 1,6)

A2 I guess I use working with others because it is what I like the best, but it is often that I use (0.5) what I have done before as well. (Amalie 1,10)

In general, the students mentioned liking emphasized resources. There were a total of ten statements about emphasized resources that were positive, while six were negative. If one ignores the textbook, however, there would be nine positive statements compared to two negative statements. For non-emphasized resources, it is difficult to draw a conclusion considering that three of the most used non-emphasized resources (Google, YouTube and Wolfram Alpha) were not mentioned by any student within statements about resources they liked or disliked. Christian, however, clearly indicated appreciation for Wolfram Alpha by drawing a heart around it when he constructed his mind map.

Subtheme 5.2.2: Not much appreciation for the textbook

The results in table 4.32 show only one student (which was Christian) mentioning that he used the textbook because he liked it, while four students mentioned that they disliked the textbook and one mentioned disliking text resources in general. Looking at statements that did not relate what one liked to what one used, (and thus are not counted in table 4.32), Benjamin did say he thought the textbook had good explanations. From the interviews with the course organizers, they all seemed aware that the textbook was not highly appreciated among the students:

And I suspect that there are pretty few who read a good deal in the textbook.

Bjø	every week they get (1.0) ehm… exercises from the textbook. Or they can sign in and do it in MyLabs, online. […] I think that most (0.5) they (0.5) work on (0.5) MyLabs exercises and so on.

Chr	My impression after talking to the clerk is that it… there is a lot of circulation on the secondary marked, so I think that book (1.0) is bought and sold again, so I do not know if the students use it that frequently.

Result 5.2.a: Unfamiliar digital resources are not appreciated

The statements where students expressed their dissatisfaction with a resource the strongest were Benjamin's description of Maxima and Casper and Christian's descriptions of Maple TA.

C3	Er… standard… (0.5) right wrong type problems (1.0) I actually hate to a high degree. We have it at the moment, and it is awful, because… Sometimes I get it wrong and then it is, either, for instance (0.5) the syntax I have entered is wrong, or it is like… well, typed a number wrong or it is, that I have done a slouch error in the book, or something. I do not know what it is, so I end up having to do the exercise over again. Often multiple times. Hate it. (Christian 3,8)

Benjamin communicated a particular dissatisfaction with his tone of voice in addition to his words when he said:

B1	Well, I do not really like Maxima, right, so I would have liked to see that we got to use other resources, like emphasizing that we used, I don't know, Matlab or something or other elsewhere (2.0) because I see the advantage to learning Maxima, to have like a… (1.0) calculation program, but exactly Maxima I feel is er… (1.5) not that good, you know. (Benjamin 2,10)

The two resources have in common that they are both digital resources used to solve tasks that were emphasized in the courses, but that were new to the students. In contrast, the students at University Beta are generally quite happy with MyMathLabs, none of the students who had GeoGebra at secondary school mentioned disliking it and Adrian quite likes Matlab from his previous experiences with it. Hence, while there is the possibility that the students disliked Maxima and Maple TA due to flaws within those two programs, it is also possible that it is particularly difficult to use digital resources that one lacks experience with, resulting in dissatisfaction with those resources.

Types of themes

Theme 4.2 (page 158) must be said to be deduced, because I did ask students specifically whether what resources they liked and disliked affected what resources they used and to what extent. That preference influences students' decisions was a working theory I had, for which there was evidence. The rest of the themes and subthemes were induced, because I did not ask about how the students' resource decisions were based on their goals, and my question about what resources they liked and disliked were not biased towards any particular results.

Theme 4.1 (page 157) is closer to a latent theme than a semantic one. While some students made statements to the effect that they used resources suitable for the tasks at hand, and one did mention the "purposes" they used it for, the students did not use terms like goal-based decisions and most of the statements the theme is identified based on are from students describing strategies that I interpret as goal-based decisions. The subtheme is also latent because it involves emphasized resources, which few students used and looks at the results across all statements. The related result, however, is semantic because it is based on statements where students did mention going to ask fellow students before going to ask the lecturer.

Theme 4.2 (page 158) is somewhat semantic, because while students did not use the term preference, they did mention using resources more if they liked them. Still, the theme is mostly latent. Most of the statements forming the basis of the theme are ones that I interpret as examples of statements that they use or would like to use a resource because they like it, or do not use because they do not like it. The subthemes also look across all the statements and are thus latent themes. The related result is decidedly latent because it establishes a connection between different students' dissatisfaction with different resources based on similarities that I, the researcher, interpret as significant, but that are not mentioned by the students.

4.4.6 Resource discovery

About the category

Students rarely talked spontaneously about how they discovered resources. During the first round of interviews, students were asked to what extent they used resources emphasized in the course and how they discovered other resources they used. Occasionally, I asked about discovery as a follow-up question when the student talked about a certain resource at length. I drew the line between theme and result at whether more than half the students mentioned a form of discovery. Table 4.33 shows the number of statements from each student that the themes, and result within this category is identified based on.

Resource discovery	A1	A2	A3	A4	B1	B2	C1	C2	C3	Total
6.1 Discovery through current education	1	0	0	1	1	1	2	0	1	7
6.2 Discovered through previous education	2	1	0	1	0	0	0	1	1	6
6.a Wolfram Alpha recommended by fellow students	1	0	1	1	0	0	0	0	0	3

Table 4.33: Breakdown of the number or statements from each student that each theme and result within the category resource discovery is based on. Results are numerated with letters.

Description of resource discovery

Decisions about which resources to use involve having a pool of resources to choose from. Students tend to choose from emphasized resources and the resources they are already familiar with from previous education. They also use search resources to find utilization resources (see subtheme 4.4.3, page 172) and several have been recommended Wolfram Alpha by their fellow students. They do not tend to actively search for new resources to use.

Theme 6.1: Discovery through current education

Students tend to make use of the emphasized resources within the courses they take, and some of the resources they used are ones they discovered through the current course.

B2 Yes, primarily I use what the course emphasizes, [Bjørnsen's] video lectures mainly, and then MyMathLabs (Brage 1,3)

The students in the project specifically mentioned textbook, formula collection, video lectures, MyMathLabs and the math wiki as resources they had discovered through the courses they were currently attending.

Theme 6.2: Discovered through previous education

While the students in the project tended to go to emphasized resources first (see subtheme 1.2.1 page 132 and subtheme 5.1.1 page 178), some also used some resources they were introduced to during their education at upper secondary.

A1 GeoGebra I believe we started using already back at (0.5) secondary. (Adrian 1,5)

Multiple students mentioned GeoGebra as a resource they used that they had discovered through secondary education, while Adrian mentioned his calculator as well and Amalie mentioned her old math books.

Result 6.a: Wolfram Alpha recommended by fellow students

Of the resources that students reported using, but did not report discovering through current or previous education, most of them were resources they can be assumed to have been familiar with from non-mathematical activities such as Google and YouTube. As such, they did not mention how they discovered it. However, three students out of the seven who in some form indicated that they used Wolfram Alpha, mentioned discovering it through recommendations by fellow students.

A3 It was a fellow student who recommended it to me. Er, he (0.5) used it when we sat in… a group. Er, I asked what it was and he explained. (3.0) And… yeah. Since then I have, well… (1.5) well, had use for it. (Andreas 1,7)

All the three who mentioned it were from University Alpha, so there is a chance that they may have been recommended it by the same student. There is also a change that Wolfram Alpha is a resource that students generally find useful and tend to tell each other about.

Types of themes

Theme 6.1 (page 185) can be considered deduced because I asked specifically about emphasized resources, while theme 6.2 (page 185) and result 6.a (page 185) are inductive. Result 6.a could be considered a semantic theme, while the themes within the category are within a grey-area. The theme relates to the wording of the students, but students mention a variety of resources, while the themes theorize general connections. I consider them more latent than semantic.

4.4.7 Quality criteria

About the category

Students were asked during the first interview if there were any resources that they liked or disliked. They were not specifically asked why they liked or disliked it, but apart from Amalie, every student indicated at least one reason. Many also mentioned what they liked or disliked about certain resources during open questions about their use of resources, or why they found certain resources useful or not very useful. Table 4.34 shows the number of statements from each student that the themes, and results within this category was identified based on.

Quality criteria	**A1**	**A2**	**A3**	**A4**	**B1**	**B2**	**C1**	**C2**	**C3**	**Total**
7.1 Simplicity	2	0	1	0	2	1	1	1	0	8
7.2 Efficiency	2	0	4	0	6	7	0	3	1	23
7.a Control of the pace	0	0	1	0	0	1	0	0	0	2
7.b Quality of explanations	0	0	1	1	1	0	0	0	0	3
7.c Breadth of functionalities	3	0	0	0	0	0	0	0	1	4
7.d Price	1	0	0	0	0	0	0	0	0	1

Table 4.34: Breakdown of the number or statements from each student that each theme and result within the category quality criteria is based on. Results are numerated with letters.

Description of quality criteria

When students make resource decisions based on preference and what is suitable for the task, they have quality criteria for whether they consider a resource to be preferable and suitable. The criteria vary depending on the student, but some quality criteria are particularly common. For instance, a resource should be easily available, allow the student to work efficiently and not be too complex.

Theme 7.1: Simplicity

For resources used in the introduction or explanation phase, students prefer resources that cover the topic in a simple way (see Celine quote below). Resources that cover the topics in a complicated matter are not appreciated.

Many students in the project considered the textbook to be too ‘heavy’ (see Casper quote below).

C1 I am not a fan of the book. It (1.5) is a bit too (2.0) heavy (0.5) really, to get through. (Casper 1,8)

C2 Ehm… (0.5) well, on our webpages, right, there are topic pages, where there is a lot of infor… – quite a lot of, ehm… (1.0) What to say? (1.5) Well, learning, I was about to say [laughs] – material, right. So there it is in Norwegian, so it is simpler. (Celine 1,2)

Theme 7.2: Efficiency

Students prefer to work quickly. For work on exercises, they prefer resources that are easy to use and easily available (see Christian quote below) to avoid wasting time. They also appreciate resources that let them quickly edit their work to correct a mistake in their solution method (see Adrian quote below). When they look up information, they appreciate resources that help them do so quickly. They appreciate video resources for allowing them to control the pace, for instance by increasing the playback speed or skipping past sections (see Brage quote below). As the only student to incorporate quality criteria in his mind map, Brage related “quick” to video lectures and searching online. Otherwise, students expressed their appreciation for efficiently through a variety of statements such as the ones below.

A1 Er, so it – it means that… (0.5) if you were to have a wrong number somewhere in (0.5) your calculation, then you can actually just (0.5) scroll up and as long as you have… (0.5) everything in the right order and use that answer button then… of course it is very easy to just update a whole list of results (Adrian 3,9)

B1 I try to work as efficiently as possible, because now it… exams are approaching quickly (Benjamin 3,5)

B2 I use the video lectures quite a bit. I think they are very nice, and very quick to look at, because you can play back faster than it is actually recorded (1.0) just to go through a topic quickly and see how you solve it. (Brage 1,1)

C3 Calculator I have started using to a smaller degree, just because when I work I usually have the PC available, so I usually just use Wolfram Alpha as a calculator. (Christian 3,1)

Result 7.a: Control of the pace

Students do not just appreciate video resources due to the features that let them view the content quicker. They also appreciate that they can control the pace and potentially watch sections over again, depending on what information they find useful at the moment. In his mind map, Brage tied "can watch again" to the video lectures. Andreas described the usefulness of video resource for controlling the pace as follows:

A3 And then I can control the pace to my preference, if there is something I am unsure about then I can stop it completely. Potentially if there is something I have (0.5) an understanding for or under control, then I can (0.5) increase the speed of the (0.5) playback. (Andreas 3,6)

Result 7.b: Quality of explanations

For explanation resources, the quality of explanations are important. Some students mentioned that specific resources had good explanations. For instance, Adrian indicated that he appreciated level of detail from the lecturer's explanations (see quote below) and Benjamin, indicated that the textbook referred back to previously learned content and explained how various results were derived (see quote below).

A3 I usually go to… (2.0) the teacher if I am stuck. If fellow students cannot help, er… (2.5). Usually I get a very detailed (1.0) calculation, very detailed *fremgangsmåte** and explains it very well. (Andreas 1,2)

*The Norwegian term "fremgangsmåte" may refer either to a solution method or to a more general approach to a task.

B1 Well, it is a bit random, and it is because the book is very good… explains quite well (1.0) and it is very good at showing (1.0) er, it usually shows quite well where things like values come from and refer to formulas that – that is refers to previous formulas and so on. (Benjamin 2,4)

Result 7.c: Breadth of functionalities

Adrian mentioned multiple times that he appreciated how many functionalities his calculator had, as well as Matlab, which he currently was not using (see quote below). Christian appreciated the multiple functionalities of Wolfram Alpha (see quote below).

A1 There are – there are not many calculators that do very much more that we get – get to bring to the exams anyway. (Adrian 1,5)

C3 Then we also have internet, where we have Wolfram Alpha. It is quite *alright* for calculating things, graphing things, finding inverse function, everything really. (Christian 1,14)

Result 7.d: Price

As the only student, Adrian mentioned that he considered the price when he decided what resources to use (see quote below). While other students did not mention the issue, every resource that any of the students indicated using was either emphasized in the course, or free to use.

A1 And then it is also (1.0) how cheap it is. Ehm (1.0) For instance, that is why I have not (0.5) paid for Wolfram Alpha and such, and (1.0) and at (0.5) the times I do not get like (1.5) when I do not get it from school, I do not have Matlab installed because it is quite… quite an expensive program. (Adrian 1,7)

Type of themes

All the themes and results tied to quality criteria are identified inductively. I exclusively asked students about quality criteria in general (and examples), not about specific quality criteria.

All the themes and results are more latent than semantic, because they look across statements from various students to theorize that students like resources that fulfill certain criteria, based on several statements from specific students who liked specific resources due to those criteria. If result 7.d (page 190) was only based on the statement by Adrian, one might consider it semantic, however, since it also takes into account knowledge on what resources all the students mentioned and whether those resources are emphasized or free of charge, I still consider it a latent result.

4.4.8 Other results

About the category

Within this subsection, there is a theme, a subtheme and a result that did not fit within either of the seven theme categories. Table 4.35 shows how many statements from each student they are identified based on.

Other results	A1	A2	A3	A4	B1	B2	C1	C2	C3	Total
8.1 Mathematics is a low priority when students are short on time	2	2	2	1	4	0	0	0	1	12
8.1.1 Taking a break from mathematics when preparing for other exams	1	2	1	1	1	0	0	0	0	6
8.a Focus on understanding	0	0	2	0	5	1	1	0	0	9

Table 4.35: The number of statements from each student that the theme, subtheme and result that did not fit within a theme category were based on. Results are numerated with letters.

Theme 8.1: Mathematics is a low priority when students are short on time

When students are short on time and need to prioritize, reportedly they tend to prioritize other subjects than mathematics. This was indicated by six students, including Benjamin:

B1 There have been many other courses that I have had – had to work on as well, so I have made math a rather low priority. (Benjamin 2,3)

Subtheme 8.1.1: Taking a break from mathematics when preparing for other exams

Students are particularly likely to make mathematics a low priority while they are studying for other exams. They seem more inclined to focus on one exam at a time if possible. For instance, Anna stated:

A4 And then I have not worked as much on math lately, because I have had other exams and other things to do than… (1.0) well, now I have started on it again. (Anna 3,2)

Result 8.a: Focus on understanding

Many students at some point used the Norwegian word for understand or understanding during the interview. Often it related to how to solve specific exercises. Four students made statements that I interpreted as either clearly or possibly relating to understanding more generally. Benjamin had multiple statements that seemed to support an emphasis on more general understanding. Below is one statement from each of the four students.

A3 I dislike the most to (1.5) have to learn (0.5) the curriculum by myself, for instance if a lecturer says that you are to read these pages in the book, understand the curriculum (1.0) then… potentially do exercises afterwards. That is a situation I… (2.0) dislike. (Andreas 1,9)

B1 Until now it has really just been to get – like, to keep pace on the understanding parts, at least, then in the exam period I can pick up with more exercises, so… A lot with textbook at the moment, not that much else, so… (0.5) just up until now, at least. (Benjamin 2,3)

B2 And then to find other solutions or other explanations if I think video lectures are hard to understand and the tex… – textbook can be a little bit (0.5) heavy to read sometimes. Then it is usually (1.5) like YouTube [Writes] or something like that that I go to, to find a different explanation. (Brage 2,11)

C1 Going to try… to get more understanding in the overview lecture while I am there, rather than to note down everything (Casper 3,6)

Type of themes:

The theme, subtheme and result in this category are all inductive, as they do not relate specifically to any questions I asked, but relate to topics that the student decided to bring up. The theme and subtheme within this category are rather semantic because the students specifically mentioned priority and other exams. The result is somewhat latent because in each instant of their use, I need to judge the extent to which the words understand and understanding relate to specific exercises or more towards a mathematical topic in general.

Chapter 5: Addressing the research questions

In the section research questions and aims, I both listed contextual questions and research questions. The research questions are directly relevant to the focus of the study, while the contextual questions are important because socio-cultural contexts affect the people within them. It is useful to learn about the context and compare features of the context to features of students' resource use, in order to theorize about the extent to which one affects the other. This chapter covers the contextual questions before the research questions. The research questions are also discussed further in chapter 6, and the discussion within this chapter is slightly curtailed in order to reduce the level of redundancy.

Among several important contextual finding, some of the most important are the differences between the resources emphasized in the course, and the predominance of successful students participating in the course. In general, University Alpha was the most focused on material resources, University Beta was the most focused on digital resources and University Charlie was the most focused on social resources.

Among a plethora of phenomena answering the resource questions, I will mention some that I see as particularly significant. Students use emphasized resources a lot, and their other resources include digital resources such as GeoGebra, Wolfram Alpha, Khan Academy, YouTube and Google, as well as working a lot with other students. Students develop schemes for general classes of situations such as learning new content normally, and when they experience difficulty. For each class of situations, they use resources for the four didactical resource purposes introduction, practice, evaluation and explanation. Their documents evolve quickly in response to changes to the context, while change within a stable context is limited. Students chose their resources primarily based on what they consider suitable for their goals, with a secondary focus on preference. Students appreciate resources that are simple and efficient, that let's them control the pace and contain explanations of high quality. Students' use of resources is affected by several factors, including what resources are emphasized; the level of difficulty; what resources they are familiar with; how familiar they are with the mathematical topic; how much time they have to study; how available certain resources are and whether they are preparing for examinations.

5.1 Addressing contextual questions

Here, I address questions about the courses and students. These are relevant when interpreting the students' statements and I consider them a pre-requisite to answering the research questions. For instance, comparing what resources are emphasized in each course to what resources students use help shed light on their decision-making process and the degree to which they follow recommendations or find resources on their own. This section essentially summarizes the results of section 4.1 (starting at page 89), as well as the students' grades and previous university experience. The rest of the student summaries may also form a basis for interpreting the results and addressing the research questions, but they are not summarized in this section.

5.1.1 CQ1: Emphasized resources within the courses

In this subsection I address the contextual question:

CQ1. What resources are emphasized in the courses at University Alpha, Beta and Charlie?

This question serves to form an important basis for interpreting students' decisions on what resources to use.

Judging from both the lecturer's and the students' comments (summarized in table 4.2, p. 92), at University Alpha there is a strong emphasis on solving recommended exercises from the textbook using pencil and paper methods. While not explicitly mentioned, I assume (from its prevalence in the app data and my personal experience with the Norwegian school system) that calculator is needed for some of the exercises and is also emphasized. There is a strong emphasis on either attending or watching streams of lectures. The lecturer reported focusing a lot on exercises during his lectures. There is a split emphasis between the textbook and the lecturer's notes (hosted on Canvas) as a source of further information. The course provides a homework help session, but none of the four students in the study expressed that they attended them. The students are allowed to make a self-written A4 sheet of paper for exams, and they are allowed to bring a formula collection to the exams. These resources can be considered emphasized by virtue of being discussed within the course. It is unclear whether students taking lecture notes, asking questions to the lecturer or working with fellow students are emphasized through recommendations. I did not ask the lecturer or students whether the lecturer recommended using said resources, nor did anyone spontaneously address it. From my experience with the Norwegian school system, I assume that taking notes is emphasized, while social resources may or may not be emphasized.

At University Beta, there is a particular emphasis on the lectures and video lectures as sources of information and MyMathLabs as a resource for finding and solving exercises (see table 4.4, p. 94). Bjørnsen additionally provides the students with a textbook and several resources by way of linking to them on Canvas. This includes SimReal, Mathcenter and the Sinus website. These appear to be emphasized to a lesser extent. Maxima was emphasized for a limited time as it was part of a project. Based on students' comments, previous exam sets are emphasized, as the lecturer solves many exercises from them as part of video lectures or lectures leading up to exams. It is unclear whether students taking lecture notes, asking questions to the lecturer or working with fellow students are emphasized through recommendations, as no one were asked about it or spontaneously addressed it. Once again, I assume that taking notes is emphasized, but draw no conclusions about social resources.

University Charlie arranges an overview lecture, an interactive lecture, a 'math lab' and a plenary session each week. The overview lecture focuses generally on the topic of the week, while the interactive lecture is focused on exercises. The math lab is a student support center with student assistants (older students), while the plenary session features a professor solving the recommended exercises for that week. In general, there is a strong focus on recommended exercises. The textbook does not seem to be emphasized that heavily, as the organizer said he suspects that the students hardly use it. The course also has a course page with theory pages and video lectures, which is occasionally referred to as a 'math wiki'. Maple TA is used for near-weekly tests. Given the frequency of the tests, I assume that they are intended to be helpful to the students and are not simply intended to help the course organizers grade the students. A compendium is provided, although it was not mentioned when discussing emphasized resources. As with the other courses, I assume that taking notes is recommended, despite no statements clearly confirming that. I make no conclusions regarding whether social resources are emphasized.

5.1.2 CQ2: Other factors characterizing the courses

In this subsection I address the contextual question:

CQ2. What other factors characterize the courses at the three universities?

(‘other factors’ referring to factors other than which resources are emphasized).

The main factors addressed that may be relevant here are the mathematical content of the courses and the grade distribution of the students within the courses. The former is important as students would likely use different resources for different mathematical topics (see result 1.d, page 138). The latter will be important when considering the extent to which the students who participated in the project were successful in the courses.

All the courses involved calculus. Christensen explicitly said that the course at University Charlie could be considered an extension of R2, the highest-level mathematics course in Norwegian upper secondary school. Judging by the extent to which students at University Alpha encountered topics they were familiar with at the start, and their descriptions of said topics, such a description seems to apply to University Alpha as well. Anna specifically said there were a lot of topics from R2 in the course. The course at University Beta is both for students at their first and second year and is a bit more advanced.

The grade distribution for the students who took the University Alpha course during that semester was negatively skewed, with an average (by the method described in subsection 4.1.1, page 90) of a weak D. At University Beta, the results on the written exam approximately followed a normal curve (weak C on average), while the folder evaluation was quite positively skewed (with an average near the middle between A and B). At University Charlie, the results of the written exam had a slight positive skew (strong C for the male average, C for the female average).

5.1.3 CQ3: Students’ previous experience with university mathematics

In this subsection I address the contextual question:

CQ3. Do any of the participating students have previous experience with university mathematics?

Previous experience may influence students' use of resources, as people with previous university experience are not undergoing secondary-tertiary transition to the same extent as the people who are attending their first university semester.

Adrian had attended one year at University Charlie before he started over on a program at University Alpha. Andreas had attended a preparatory course for university mathematics at University Alpha. Both students at University Beta attended their second year at university. Amalie, Anna, Casper, Celine and Christian had no prior experience with university mathematics. Anna spontaneously shared that two years had passed since she attended secondary school. She considered it relevant information when she discussed her strategies for refreshing her memory when familiar topic came up.

5.1.4 CQ4: Students' performance in the courses

In this subsection I address the contextual question:

CQ4. How well did the participating students do in the course that was studied?

This contextual question is important for interpreting the generality of the results and whether they are likely to apply to most students within university mathematics in Norway or primarily to students at a certain level.

Amalie did not give permission to use her grade when she signed on. Adrian achieved an A, placing him somewhere within the 94^{th}-99^{th} percentile at University Alpha (see table 4.1, p. 90), while Anna achieved a B (88^{th}-93^{rd} percentile) and Andreas a D (52^{nd}-73^{rd} percentile)

Both Benjamin and Brage achieved an A at the folder evaluation, placing them within the 39^{th}-99^{th} percentile in the course at University Beta (see table 4.3, p. 93). Benjamin also achieved an A in the written test (91^{st}-99^{th} percentile), while Benjamin achieved a B (68^{th}-90^{th} percentile).

Casper, Celine and Christian all achieved grade A, placing Casper and Christian within the 77^{th}-99^{th} percentile of male students in the course at University Charlie (see table 4.5, p. 95) and Celine within the 85^{th}-99^{th} percentile of female students in said course.

In conclusion, the students who participated in the study generally performed quite well in the course. Amalie was the only one whose grade was unknown and Andreas the only one whose grade was known and only slightly better than average within the course he attended. It may be that skillful students were more motivated to participate in the project. There is also a chance that participating in the project increased the students' motivation to do well at the course. The high frequency of successful students means that there is a possibility that the results of the study would differ, given a sample that was more representative in terms of level of accomplishment.

5.2 Addressing research questions

In this section, I address each research question in light of the data. Both the students' summaries and the themes identified are relevant to the research questions. For some research questions, the results within multiple theme categories are significant, and for some only one. I do not make reference to results found in the literature in this section. Comparisons between the results within the study and ideas within the field of research is the topic of section 6.1 (page 225).

5.2.1 RQ1: Resources used and extent of use

In this subsection, I address the first research question:

RQ1. What resources do undergraduate engineering students use in mathematics courses and to what extent?

Students use the emphasized resources in their courses quite a lot. As identified in subtheme 1.1.1 (page 130), they use resources that are allowed at the exams when they prepare for exams. Subtheme 5.1.1 (page 178) proposes that they tend to attempt to solve a problem using emphasized resources first and possibly use non-emphasized resources later. This may be because they almost exclusively used emphasized resources when they find the mathematical topic at hand to present minimal challenge to them, as described in theme 1.2.1 (page 132). They may assume that a topic is easy to them until experience the opposite, hence attempting to apply their resources used for easy tasks first. Subtheme 4.1.1 (page 157) states that for introduction to a topic, students almost exclusively use emphasized resources, and according to theme 6.1 (page 185) one of students' primary ways to discover resources were through the emphasis on said resources within their current education.

As discussed in subsection 5.1.1 (page 194), the resources that are strongly emphasized at University Alpha are lectures, lecture streams and textbook exercises, while other emphasized resources included textbook chapters, lecturer's notes, students' lecture notes, homework help, exam sheet, formula collection, calculator and pencil & paper. Looking back at the semester, the participating students did not report using homework help. They focused particularly on textbook exercises, pencil & paper, calculator and either lecture or lecture streams. They also focused on formula collection and exam sheet around the time of the exams, as well as previous exam sets, which may or may not have been emphasized in the course. The other emphasized resources were used to a lesser extent.

At University Beta, there is a strong emphasis on MyMathLabs, lectures and video lectures, while other emphasized resources include textbook, Canvas, SimReal, Mathcenter, the Sinus website, Maxima, students' lecture notes and previous exam sets. Both students in the project focused on lectures and on previous exam sets leading up to exams. Otherwise, Benjamin seemed to focus mainly on textbook and video lecture throughout the year and MyMathLabs leading up to exams. He also used "simulations" a bit (presumably within SimReal). Brage focused heavily on MyMathLabs exercises.

At University Charlie, there is a strong emphasis on overview lectures, interactive lectures, math lab, plenary session and recommended exercises, while other emphasized resources included textbook, compendium, course pages, video lectures, Maple TA and students' lecture notes. The students in the project all focused on the strongly emphasized resources; their own lecture notes and the course pages. They all used the textbook, although Casper and Celine did not like it much, and Maple TA, as it was mandatory. Only Casper used the compendium a bit. He also used the videos available through the course page. Casper and Christian mentioned using previous exam sets, which may or may not have been emphasized in the course.

Looking beyond emphasized resources, Wolfram Alpha and GeoGebra were commonly used by the students in the project to check answers or plot graphs (which was one of the three main categories for checking answers, discussed in subtheme 4.3.1, page 162). Popular resources to find information included YouTube and Khan Academy or simply searching the internet, often using Google’s search engine. YouTube and Google could lead students to resources that they utilized. See subtheme 4.4.3 (page 172) and the working definition on page 27. The lecturer and fellow students were popular social resources that could be used to discuss general topic or individual exercises, although as discussed in subtheme 2.2.2 (page 148), the extent to which students worked with others varied. Some students also used resources that no one else mentioned. Amalie used her mother for discussion and her notebooks from secondary to refresh her memory about familiar tasks. Adrian used folders to organize his notes. He additionally mentioned excel as a resource, although he did not appear to have used it in this specific course. Brage used the screenshot features of his computer to be able to look at certain problems in MyMathLabs later. Christian occasionally wrote on his windows, where he found it easier to edit the steps within his solution of a problem.

In general, students seem to use emphasized resources, social resources, search resources and digital calculation tools quite a lot. In the case of emphasized resources, all the students used them. For social resources, search resources and digital calculation tools, however, the degree to which they use resources within the other categories varies greatly. The popularity of emphasized resources can be interpreted in various ways. From a socio-cultural perspective, the fact that they are emphasized within the context of the course is in itself a motivation for people to use it. Interpreted through the documentational approach, students may gain a lot of experience with resources that are strongly emphasized, enabling them to develop extensively develop schemes involving said resources. If one focuses particularly strongly on activity being goal-oriented, as discussed in theme 5.1 (page 176), then one may theorize that students follow the rationale that the person organizing the course presumably have a reason to emphasize the resources that they do. These resources may be particularly well suited to solving the tasks within the course efficiently. Hence, students try the presumed more efficient resources first, and only go to other resources if they are unable to fulfill their goals with the emphasized resources.

5.2.2 RQ2: What characterizes the schemes developed

As established in the theme category for schemes of utilization, students have a variety of strategies both for working alone and working with others. In this subsection, I address the second research question:

RQ2. What characterizes the schemes that students develop?

While my research design is less equipped to gather data on schemes of utilization compared to most research using the documentational approach, some schemes can be identified. I think viewing students' strategies in light of their quality criteria (see page 187 and onwards) is a good starting point for discussing some of their schemes, while other schemes should be seen in light of what purposes the students use resources for.

Some of the students' schemes involve making information more accessible to themselves in the future. This is the reason why Brage takes screenshots in MyMathLabs and Adrian organizes his notes in a folder. It may also be one of the reasons why so many students use lecture notes. For students at University Beta and University Charlie, the lectures themselves are not available afterwards. However, through own notes, one has access to some of the information. At University Alpha, both videos of the lecture and the lecturer's own notes are published. However, some still prefer to take notes on their own.

Other schemes involve engaging with information more efficiently. This may be a second reason why someone at University Alpha would use their notes from lectures rather than look at videos of the lectures. In their notes, they can condensed the information considerably. Benjamin was particularly concerned with efficiency, and for instance found the textbook to be a more efficient source of information than the lecture videos. Strategies for efficiently also include increasing the playback speed of videos and skipping sections with information that the student does not need at a given point in time. Students can also rewatch the parts of the videos that are the most relevant to their goals at a given time and focus more on those parts. In a sense, increasing the accessibility of information can be considered part of efficiency (theme 7.2, page 188), as it reduces the amount of time it takes to find and engage with said information later on. Some strategies deal specifically with how to efficiently correct one's errors, such as

Adrian's strategies for solving exercises with his calculator and Christian's preference for writing on his windows.

Some of students' scheme involve how to find relevant information. Anna for instance, marks down what she considers particularly important after taking notes during a lecture. Separating relevant from irrelevant information might be particularly useful when using search resources, as one finds a great amount of information when using such resources. However, this was not discussed very much by students. Celine did demonstrate how she used Google to find information, and some theorems-in-action were obvious. For instance, when she entered 'Unity' in the search field, she could tell by reading the text under each result that the first search results were not about mathematics. She proceeded to enter 'Unity math' and then 'unity in math' in search of more relevant results. One explanation why students tend to use the emphasized resources a lot (see subsection 5.2.1 page 198), may be that the information gained through interacting with emphasized resources is considered particularly relevant. After all, the resources are emphasized by people involved in the course, and the student are likely to trust their judgement. The emphasized resources may also be more efficient, since students who use search resources may spend more time separating relevant from irrelevant information, than they would with an emphasized resource.

The students have a multitude of schemes for checking their answers when they work on exercises, as is the topic of subtheme 4.3.1 (page 162). Looking at the answers in the textbook; looking at solution suggestion in MyMathlabs; using Wolfram Alpha, GeoGebra or calculator to obtain the correct answer; modelling the problem in GeoGebra; asking the lecturer, a parent or student assistants and discussing with fellow students are strategies that students in the project mentioned using. Many of these strategies additionally help the student locate the source of error if they got the answer wrong. Using social resources, someone may discover the mistakes for someone else. Using digital resources, students may locate errors by adjusting one part of their solution method at a time and observing the resulting changes.

The students hardly discussed strategies for their initial attempts to solve exercises. Adrian, however, mentioned his preference for pencil and paper methods and how he saw it as important to know them. He said that if you for instance solved it by spreadsheet, then you may not know how to solve it by pencil and paper "when it counts". Logically, one could make the reverse argument that if you solve it by pencil and paper, you may not know how to solve it by spreadsheets when it counts. Thus, I assume that there is an implication that "when it counts" refers to exams, and that the exams are focused on pencil and paper methods.

That students focus on examinations is another aspect that seems to characterize their schemes for using resources. As subtheme 1.1.1 (page 130) attests to, they tend to emulate the exam situation when preparing for exams. They use previous exam sets to find similar mathematical problems to solve and have a tendency to just use the resources that will be allowed during the exams themselves. This is probably due to an understanding that the exams are important to their future endeavors and that it constitutes a situation that differs from their work throughout the year, especially in terms of what resources are available.

When students work with their fellow students, they generally prefer smaller groups, often working with two or three fellow students (see subtheme 2.2.1, page 147). Andreas specifically mentioned reducing noise and distractions as a motivation behind such a group size. There were many individual differences for how students preferred to work with others. Some preferred a lot of discussion. Both Andreas and Benjamin learned a lot from explaining something to others as well as discussion. Adrian liked having people to help him look for "dumb" mistakes. While Amalie and Andreas strongly preferred working with others, Casper only found it useful if he and his fellow students were at a similar level of skill. As a result, Casper stopped working with others during the semester.

In summary, students develop a variety of schemes and there is a lot of individual differences in terms of the schemes they arrive at. However, the schemes tend to be rooted in what I will call *study needs* that are more generally shared. Students have a need to separate relevant information from irrelevant information (relevant in the sense that it helps them achieve their goals related to the course). They need relevant information to be available for them to access quickly whenever they need it, and they need to be able to work efficiently. They need to be able to solve exercises and check their work afterwards.

When it comes to working with others, the students' study needs seem to differ. I will use the terminology that some students are more *individually minded* and some are more *socially minded*. A student who feels like they learn more from working alone is individually minded while one that feels like they learn more from working with others is socially minded. I do not use the terms to describe the extent to which students with others, just the degree to which they say that they learn from it. For instance, Andreas did not work much with others, but it was due to factors beyond his control. Statements like the following indicate that he should still be considered a socially minded student.

A3 I like the most to work in a (0.5) active and (1.5) well (0.5) coope… – cooperatively minded group, people who like to talk, people who like to (1.5) shoot ideas. Er… That is probably the environment I enjoy the most. (Andreas 1,9)

Brage on the other hand, indicated that he works roughly as much alone and with others, but generally learns more from working alone.

B2 I try to learn it myself (1.0) on my own, first, because I feel like I get more (1.0) from contemplating a problem and then figure it out, rather than to just get – be told the solution right away. (Brage 1,8)

The same seems to be true for Christian, who worked quite a bit with his friends, but it seems to be for social reasons rather than because he learned better. The terms individually minded and socially minded should not be understood as completely binary, as a person may learn a lot from both working alone and with others. Benjamin, for instance, both reported learning a lot from working alone with the textbook and video lectures and learning a lot from discussion and explaining something to someone else. Looking at all the students, Adrian, Brage, Casper and Christian seem more individually minded, Amalie, Andreas and Celine more socially minded and Anna and Benjamin seem to be a combination of both.

For socially minded students, discussion is an important study need and they have strategies that they develop based on that need. It is not as important for students that are primarily individually minded.

5.2.3 RQ3: Classes of situations

In this subsection, I address the third research question:

RQ3. What classes of situations do students develop documents for?

I use the term situation is used with a wider definition than what is common when used as a theoretical term related to the documentational approach (Vergnaud, 1998; Gueudet & Trouche, 2009). See my working definition on page 27.

I also discuss nature of some of the classes of situations. In particular, I think the students' goals related to didactical resource purposes characterize these classes of situations. Classes of situations can be interpreted at various levels of generality. One could interpret the didactical resource purposes (DRPs) as classes of situations, or consider them phases within another class of situations. Primarily, the theme categories class of situations (page 128) and didactical resource purposes (page 155) are relevant to this research questions. The former corresponds to a more general interpretation of the term.

Students develop rather general documents for broad classes of situations. Each student has a prime document for learning mathematics. It applies to situations that do not deviate much from what they consider normal within their present educational context. Discussion of how they use resources differently in varying situations can take the form of discussing what changes to situational factors cause them to use resources differently from the prime document. Other classes of situations are defined by how the situational factors differ compared to the prime document.

Students have a document for exam preparation (see theme 1.1, page 130). They work a lot on previous exam sets, generally using only the resources they will have available during exams in order to emulate the exam situation (see subtheme 1.1.1, page 130). Christian abandoned all online and social resources during the last week of exam preparation and used only resources allowed during exams. Within some courses in the study, the lectures were organized with an increased focuses on exam-relevant information and videos on the solution of previous exam problems were released. Students may work more with others or work more efficiently during exam preparation. In general, they tend to work a lot more during exam preparation than they otherwise do, as evidenced by app data from all the students who filled in information during exam preparation. Benjamin increased the average length of his study sessions from 1.85 hours throughout the year to 3.4 hours during exam preparations and used 3.8 resources per session on average, as compared to 2.7 throughout the year. Casper worked 25.3 hours a week during exam preparation, as compared to his average of 6.6 hours for the rest of the course, while Christian increased his average week from 10.5 hours throughout the year to 19 hours during exam preparation. The schemes that students develop for exam preparation vary, but everyone appears to have exam preparation as one of their classes of situations.

Difficulty is another situational factor that affected all the students in the study, although four of them only made a single statement that related to it. Discussing the impact of difficulty with them revealed that the prime document consisted primarily of emphasized resources, and to some extent fellow students. When students experience difficulty, they tend to use social resources more and they tend to use more non-emphasized resources such as web searches, online video resources and digital calculation tools. To a lesser extent, there may be differences between the emphasized resources that students use normally and the emphasized resources they use when they experience difficulty. The students who mentioned difficulty several times generally reported that the course became harder as time went on. Studying transition, Thomas, de Freitas Druck, Huillet, Ju, Nardi, Rasmussen and Xie (2015) argues that students' preparedness for calculus is going down, while the degree to which the difficulty of calculus courses is being updated is merely moderate. This may lead to students perceiving introductory calculus courses as more difficult than students in their position previously did. Hence, the relevance of this class of situation for students of mathematics may be increasing.

In the planning phase of this project, I had a working hypothesis that students would use resources differently when they worked with others compared to when they worked alone. While students did not mention it spontaneously, they did answer in the affirmative that they used resources differently when they worked with others. In particular, they reported a lot of discussion when workin with their fellow students, and they relied more on text resources, while hardly using digital resources. Hence, working with others can also be considered a class of situations.

Beyond these three classes of situations, there were large individual differences in terms of what situational factors students said led to them using resources differently. Amalie, Brage and Celine's statements focused on having different strategies for encountering tasks that were familiar to them from previous education. Andreas and Celine focused on having to adapt to other people's priority, because the extent to which they could work with fellow students was partially dependent on said fellow students. Andreas additionally mentioned working differently leading up to mandatory assignments. Benjamin focused on having different strategies for when he did not have much time to spend on the mathematics course, such as skipping exercises and using the textbook rather than the video lectures. While it was a working theory that different areas of mathematics could count as different classes of situations, only Adrian and Andreas confirmed that they used resources differently for some topics, mentioning geometry specifically. The others said that there was no difference within the course. However, it should be noted that there was not much geometry in the three courses being studied. The answers may have been different if there had been a larger rain of topics in the course or the students had attended several mathematics courses during the semester, with different foci.

It is worth noting that given the nature of the interview design, most of the classes of situations were brought up spontaneously. That a student mentioned a class of situation could be taken as evidence that it was significant to them. However, one should not conclude that because a student did not mention a class of situation, it has no significance to them. For instance, I imagine that any student faced with time shortage would develop different documents for such a class of situations. The data does not necessarily disprove that assumption. Instead, it may indicate that only Benjamin faced time shortage that was severe enough for time shortage to constitute a different document.

All the classes of situations that I mention above are at high levels of generality. While still quite general, DRPs are more specific, in that they separate the process of engaging with a new topic into phases, each of which could either be considered a class of situations or a phase within a class of situations. It is important to note that students do not necessarily move chronologically from one phase to another. Introduction always occur first and is not revisited. For the other three phases, students move between them frequently and the order of the phases is not set. Figure 5.1 illustrates the orders in which students may engage in the various didactical resource purposes.

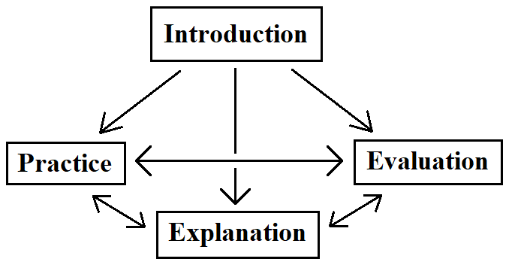


Figure 5.1: Phases of students' engagement with mathematical content. When learning about a new topic, students first enter the introduction phase. Afterwards, they may engage with the phases of practice, evaluation and explanation in any order and enter each phase any number of times.

At first, students enter the introduction phase (see theme 4.1, page 157), in which they learn the basics of a mathematical topic. At this stage, they use almost emphasized resources which involve minimal input on their part. Resources include the textbook and lectures with one-way-communication. At this stage it can be assumed that students do not know enough about the topic to ask relevant questions and actively pursue information. They need to be told what mathematical objects and relationships are involved and get a sense of what terminology and rules are important to the topic.

The practice phase (theme 4.2, page 158) involves working mathematically. It can involve solving exercises, exploration or modelling, but within the study it almost exclusively involves solving exercises. Students tend to find exercises through emphasized resources, such as MyMathLabs or recommended exercises in the textbook. These exercise recommendations are communicated by the lecturer either during a lecture or by publishing them on the course pages. For solving the exercises, they attempt to solve them through emphasized resources first, and if they do not succeed, they look to other resources (subtheme 5.1.1, page 178), including increased use of social resources. A variety of resources is used for the practice phase (subtheme 4.2.1, page 159). Students view solving exercises as quite important (subtheme 4.2.2, 161), and particularly important for performance during the exams.

It is worth considering in what way exercises are important to students. Within the Norwegian school system, the term *mengdetrening* (rough translation: practice by volume) is often used to communicate a view that exercises are important to establish and solidify ones understanding of the theory. Such a view is often reflected in the amount of exercises students in elementary and secondary school is expected to learn. Benjamin specifically used the term *mengdetrening* when talking about MyMathLabs. A contrary view is that excessive emphasis on exercises that can be solved using routine procedures gives students a narrow view of what mathematics entails. The view is that it leads them to see ability to solve routine exercises as more important than understanding of theory and ability to apply it to unfamiliar problems. For instance, a reform to the Norwegian school system set to take effect autumn 2020, focuses more on generalization, abstraction, argumentation, reasoning, modelling, exploration, problem solving and practical uses (Utdanningsdirektoratet, 2020).

Within the study, all statements about practice could be interpreted as seeing exercises as important for their own sake. A few statements could also be interpreted as using the exercises to solidify one's understanding of the theory. Amalie said she learned more through doing exercises than just reading theory (see quote at p. 147), and Christian suggested that exercises were essential because mathematics was a "repetition course" (p. 96). However, these statements are open to be interpreted as supporting either view, depending on what the goal of the learning and the repetition is. The statement that most clearly communicated that a student viewed exercises as important to solidify ones understanding of the theory, came from Per during the practice interview. He expressed that in his mind map, where he separated between learning new material and repetition, exercises related to both processes.

Per I think that, you work with exercised to learn it, right… the new material as well.

Previous experiences with mathematics education are likely to have affected students' understanding of how important exercises are and why. Their statements either support the interpretation that students view exercises as important because they have particular importance in school mathematics, or mathematics in general, or can additionally be interpreted as supporting a view that exercises can be the means to understand the theory better.

When investigating students' interactions with the textbook in German secondary schools, Rezat (2013) also used the term practice to describe students' work with exercises. He identified three ways to practice using the textbook, two of which involved strategies for finding similar exercises to ones the students had worked on previously. Position-dependent practice involved students working from the assumption that the exercises in the book that immediately followed an exercise they had solved previously, would be similar to said exercise. Salience-dependent practicing involved looking at the surface features of exercises to find similar exercises based on visual similarities. I would argue that those strategies speak to how important the skillset of identifying types of exercises and being able to solve various types of exercises through rehearsed techniques appears to be when one studies mathematics in secondary school.

Evaluation (theme 4.3, page 162) can be used to evaluate one's learning habits, as evidenced by the excerpts related to result 4.3.a (page 168). More commonly, it is used to check answers. Students may also use resources that enable them to pinpoint what mistake in their solution method led to the wrong answer. The way students talked about checking their answers seemed to reflect a view that the answer itself is not important, but the solution method is. Checking the answer was described as the first step to see if their solution method worked. For instance, Anna said that she only uses the answers in the textbook to check if she has the right answer. When students said that they obtained an answer through GeoGebra or Wolfram Alpha, they did not describe it as their solution method, but rather as a way to obtain the correct answer in order to check if their solution method worked. This might indicate an attitude that understanding of how to solve exercises through pencil and paper methods is particularly important. Other solution methods are merely a means to an end.

After the introduction phase, students have established a basic framework for the topic and are able to identify aspects that they want to understand better. This enables them to engage in a more active search of information. The explanation phase (theme 4.4, page 169) can consist of looking up formulas and minor facts, or more generally engaging in repetition on a topic or trying to deepen one's understanding. One particular form of explanation is to engage with resources similar to introduction for the purpose of additional explanation (subtheme 4.4.2, page 172). Using resources for additional explanation stems from a view that one can gain more understanding of a topic by getting information from multiple sources. Like with exercises, students often go to emphasized resources for explanation first. If they do not find what they are looking for, search resources such as Google and YouTube's search functionalities are often used (subtheme 4.4.3, page 172).

The third type of practice through textbook interaction that Rezat (2013) identifies, is one that I would classify as explanation. Rezat found that the mathematics textbooks were structured with different types of "blocks", enabling students to separate introduction to a topic from exposition, worked examples, exercises, and so on. Rezat uses the term block-dependent practice to describe the strategy in which students used the block structure to identify and read only certain parts of the textbook, such as formulas or worked examples. This is what I refer to as an active search for information. The students may decide even before opening the textbook to look for a worked example for the type of exercise they are currently struggling to solve. The students know exactly what type of information they wish to find and have strategies for how to find it.

In summary, students have a prime document, for which the class of situation is all situations in which they are to learn a new topic, and in which there are no factors that cause the situation to differ considerably from the 'normal' circumstances. Other classes of situations include the students' experiencing the topic as particularly difficult; learning while working along fellow students; finding the topic to be familiar; lacking in available time; having more or less access to certain social resources or working on topics within particular areas of mathematics. There are also the classes of situations that does not involve learning something new, but rather solidifying one's current understanding and skills leading up to assessment, such as working on mandatory assignments or preparing for exams. Within the prime document, there are the four phases of introduction, practice, evaluation and explanation. The DRPs can be considered phases within other documents as well, but whether they are all present depends on whether that document still concerns learning new topics. When preparing for exams, for instance, the DRP introduction may not be relevant. For a less general interpretation of class of situations, one could consider the DRPs to be classes of situations for which students develop documents that are subdocuments of the prime document.

5.2.4 RQ4: The evolution of documents

In this subsection I address the fourth research question:

RQ4. How do students' documents develop over time?

When students report changes to their use of resources, they may just report major changes, and not minor refinement of certain strategies. The nature of the major changes can be of at least four types. One is that they have used new resources or developed new schemes of utilization simply through increased experience. The classes of situation and the goals are the same, but upon reflection, the student have developed new strategies for how to use resources in order to achieve their goals. These are changes through reflection. The second and third type of changes are new types of classes of situations and a new set of emphasized resources. Both types are significant changes to the context, and I call them changes through adaption. New classes of situations force the students to develop new documents. With changes to the set of emphasized resources, changes are not always a necessity. If resources within students' resource systems are no longer available, it necessitates a change to their strategies, but it could be in the form of relying more heavily on another resource already in their resource systems. Students may be inspired to appropriate newly emphasized resources into their resource systems, particularly if the resources are mandatory or heavily emphasized, or they may not. The last type of change is also a change to the context, but is simply a matter of some classes of situations being activated more. Hence, the students' documents have not changed, even if they have used some resources more or less recently.

Students within the project generally made statements to the effect that their use of resources had not changed, or reported changes that could be interpreted as a certain class of situations being activated more or less. For instance, students reported increased difficulty over time, leading them to activate their document for experiencing difficulty more. This may lead them to, for instance, work more with others than previously, as was the case for Anna (see theme 3.1, page 151). As few changes were made to the mind maps, and most of the changes they made were reported to be something they had forgotten to include the last time, students' documents appeared to be rather stable, with few major changes.

The changes that did occur generally related to adaption. For instance, Benjamin experienced being behind the intended learning curve within the course in terms of learning to solve exercises. This could be considered a new class of situations for him. It led him to use several features of MyMathLabs more. For Andreas, a new class of situation was that he was unable to find times when he could work with others. In response, he did not to go to campus much and viewed lecture streams rather than attending lectures. What was difficult to label was students' encounter with the exam period. It was hard to tell whether it was a new class of situations to students or whether it was similar enough to their experiences from upper secondary school that they simply used or made refinements to a previous document.

Some changes to students' documents were changes to what resources were emphasized. Celine found that there were fewer resources provided on the web page in her second semester mathematics course. In her case, she decided to focus more heavily on one resource already in her resource system, namely student assistants (see subtheme 3.2, page 152).

Often, changes to the emphasized resources and new classes of situation would come at the same time. For instance, the Maxima project at University Beta both added a resource that was heavily emphasized for a while and introduced a class of situations for programming tasks. While this led Brage to develop a document for programming tasks, including how to search for information on how to use Maxima, there was no indication that he incorporated any aspect of his new strategies into his other, pre-existing documents.

Presumably, the biggest change to classes of situations and resources emphasized come from the transitions from secondary school to tertiary school, as well as attending new courses within a university. The information on those changes was rather lacking, as it was not a focus in the interview questions. However, the question about how students discovered the resources that they used, showed that a significant number of resources were discovered through the current course and were not used previously. Some students also spontaneously compared their current use of resources to their use of resources within a previous educational context. Christian reported interacting with the textbook after class during secondary, while at University Charlie he did so prior to class in order to have time to solve exercises. Adrian reported using GeoGebra a lot more previously.

Students at University Charlie were interviewed at the start of the next semester. Thus they were able to report on changes between courses, such as the one's from Celine about fewer emphasized resources.

From the changes that students reported, there were only three that I would consider changes through reflection (see theme 3.3, page 154). At the start of the semester, Christian had planned to use the compendium during the exam period, but upon reflection, he scratched it from his plans and during the second interview he said he would rely heavily on previous exam sets instead. During the exam period, Amalie reflected on the benefit of using the formula collection and wished that she had been more familiar with it as a resource. Thus, she decided that she would start using it more throughout the next semester. After the end of the first semester, Casper reflected on taking notes and decided on a change. He would more on the essentials, rather than copying everything the lecturer wrote.

It is unfortunate that so few students were interviewed after the exam period, because I theorize that changes through reflection might be more prevalent during that period. After all, many of students' goals link directly to exam performance. During exam preparation, students may be more inclined to notice how well they have learned the mathematical content and reflect on what they wished that they had done differently throughout the semester. It is also logical for students to evaluate their strategies once the course is done, as many activities are evaluated after their conclusion. As it stands, the changes through reflection reported by Amalie and Casper happened during or after the exam period and I would have liked to know if more students made changes at that point in time.

The stability of students' documents from interview to interview is intriguing considering most of the students attended their first semester at university. My working hypothesis was that the students' documents would develop a lot over the course of their first semester, as secondary-tertiary transition may necessitate a significant update to their documents. However, it appears that by the time of the first interview, approximately one month into the first semester, the students had already made most of the major changes to their documents. This indicates that students adapt to new contexts by updating their documents quite quickly and that said documents quickly become stable.

Overall, my interpretation of the evolution of students' documents is that students generally do not reflect on resource use and continuously make major changes to it. Major changes to their documents primarily take two forms. One is that they can be in response to a major change to the context of the current course. If so, the students tend to update their strategies quite quickly. The second is that it can be based on reflection on how well their current strategies enable them to achieve their goals. If the latter, however, said reflection primarily takes place after the conclusion of a course rather than continuously throughout the course.

Admittedly, the last idea is founded on less data than the former. There is also a great lack of data on more subtle changes to students' documents, such as specific techniques that students develop for how they use individual resources. My working theory is still that minor changes occur frequently when students interact with resources. However, they may be small enough that students do not reflect on them or do not consider them important enough to share during the interviews. Students neither talked about their current minor strategies nor about the change.

5.2.5 RQ5: Students' decisions regarding resources

In this subsection I address the fifth research question:

RQ5. How do students decide on what resources to use?

Related to the evolution of students' documents, I proposed that students did not actively reflect on and develop their documents throughout a semester. Even when they did make changes, the changes related to the extent to which and manner in which they were going to use certain resources. Students do not actively search for new resources to incorporate into their resource system. In general, my interpretation of students' decisions about resources, is that they choose within the pool of resources they are familiar with. They use the current context and previous educational experiences in order to determine which of these resources are suitable for their current goals. Beyond that, they use preference, which is tied to a set of quality criteria that they judge resources by.

The students in the project rarely talked about how they discovered resources spontaneously, and were only asked about discovery of resources through a general question during the first interview. I identified three trends from their answer. They used resources that were emphasized in the course; resources that they were familiar with from previous education and in the case of Wolfram Alpha, resources that they were recommended by fellow students. Looking at the resources that students actually use (see subsection 5.2.1, page 198), there were a few resources that were not accounted for. YouTube, Khan Academy and Google are resources that were not emphasized in any of the courses and I consider it highly unlikely that they were emphasized in the students' previous mathematics education. An educated guess is that YouTube and Google are resources that students are familiar with from a multitude of non-mathematical activities and that the students know to be useful resources for a wide range of information, leading them to deduce that mathematical content can also be found there. Khan Academy may have been discovered through recommendation or possibly through an online search. One statement by Brage indicated that he was going to start regularly using a web page he found through an online search. Otherwise, it seemed like students used search resources to find utilization resources (see subtheme 4.4.3, page 172).

Looking at the tables tied to subtheme 4.4.1 (page 170), it appears that the use of search resources varied depending on the university. Every student from universities Beta and Charlie that participated in the project mentioned using at least one search resource, while no one at University Alpha mentioned using any. I theorize that this observed difference is due to University Alpha emphasizing fewer resources and due to the University Alpha course being more similar to secondary education. I think students at University Alpha were less aware of the breadth of options available to them, because the institutional context of University Alpha reminded them of secondary education, within which they had less opportunity to choose their resources. Universities Beta and Charlie provided a greater breadth of resources and may have communicated more clearly to the students their opportunity to choose between them. This may also have led them to be more aware that their choices extended beyond emphasized resources. It is an interesting fact that all the three students who used video lectures for explanation, additionally used YouTube videos from other people. It is also worth noting that the student from University Alpha who mentioned the greatest breadth of resources was Adrian, who had previously attended a similar course at University Charlie. One comment from Anna particularly expressed a lack of experienced agency. When she was asked what resources she liked to use (spontaneously also answering whether what resources she liked affected whether she used them), she said.

A4 I guess I use (1.0) all of them anyways (Anna 1,10)

While the idea having a wide range of emphasized resources leads students to become more aware of their agency regarding resources is neither supported nor contradicted by statements from the students themselves, I think students are unlikely to reflect on such issues, so I do not think they would mention it if it were the case. While it requires further study, I think it is a suitable theory to explain the differences observed between the universities.

That students' resource decisions are primarily goal-based and secondarily based on personal preference is the topic of themes 5.1 (page 176) and 5.2 (page 179). These ideas are directly supported by student statements to that effect in response to questions during the first interview. It concerned whether students used resources more if they liked them and more generally, what they made their resource decisions based on. Decisions being goal-based was also indirectly supported by students describing resource strategies that involved a set of resources that they would use first, for a given type of problems, and a set of resources that they would use as a plan B. Decisions being preference-based was indirectly supported by examples of students mentioning that they liked a resource, mentioning that they disliked a resource or describing that they liked certain resources more than certain other resources used for similar purposes.

Within the students' strategies that had a plan A, plan B structure, emphasized resources were usually plan A and non-emphasized resources such as search resources and digital calculation tools were plan B (see subtheme 5.1.1, page 178). I theorize that in terms of resources used to find information, emphasized resources tend to be more efficient for the students, particularly if they are made specifically for the course, because the majority of the information they provide is relevant to the goals that student have for the course. In contrast, a search resource will help students find a wide range of information, the relevance of which varies greatly. If students are unable to find what they are looking for with emphasized resources, the breadth of information available through search resources is useful to them. While it takes more time, because they need to separate relevant information from irrelevant information, there is a good chance that they eventually find what they are looking for.

There is one significant exception to plan A resources being strongly tied to the context and likely to be more efficient while plan B resources hold a larger breadth of information. Communication with the lecturer was almost exclusively a plan B resource. Considering how involved the lecturer is with the course, they ought to be considered a highly effective resource for finding information that is relevant within the course context. There is nothing within my data that explains this phenomenon. However, I consider it likely that the reason is the same as Gueudet and Pepin (2018) theorize when they found similar results in their study. In their interpretation, the students assume the lecturer's time to be very valuable and assume there to be a norm that they are not to take up an unnecessary amount of the lecturer's time.

Many of the students' statements about plan A and plan B strategies gave insight into the kinds of goals that they used resources for. I think there is a strong relationship between goals and classes of situations. A class of situation can be defined by the type of goals the student is pursuing in that situation. I would argue that this is the case with didactical resource purposes (DRPs) as well. For instance, introduction, if seen as a class of situation, is defined by goals such as getting an overview and a basic understanding of a new mathematical topic. I theorize that students have at least one resource for each DRP, and usually several resources incorporated into a plan A, plan B strategy. I think one of the reasons why Wolfram Alpha alone appears to be a resource that spreads through recommendations from fellow students may be that it serves purposes that few other resources serve to the same extent. In particular, it is a very good resource to use to check your answers through the digital calculation tools strategy, which is one of three general strategies that students use a lot to check their answers (see subtheme 4.3.1, page 162).

Within the project, the resource that students mentioned liking the most, was fellow students, while the resource they disliked the most was the textbook (see subthemes 5.2.1, and 5.2.2, respectively, starting on page 181). In the case of fellow students, they were mentioned both as preferable for social reasons, and able to assist students' pursuit of goals in the mathematics course through discussion, explanation and checking answers. The textbook was mentioned as less than preferable because it was ‘heavy’ or ‘cumbersome’. Part of the reason may be that the textbooks in all the courses were in English, rather than Norwegian. Another part of the reason may be that the textbooks were not made specifically for the courses. The words ‘heavy’ and ‘cumbersome’ suggested that the textbook did not fulfill the quality criteria of simplicity (theme 7.1, page 187), which I derived from eight statements by six of the students.

Most of students’ statements about features that they considered positive in a mathematics resource, can be covered under the umbrella of efficiency (theme 7.2, page 188). It can be interpreted as a criterion both for goal-based decisions and for personal preference. The efficiency of a resource is determined by how quickly a student can access it and how quickly they can achieve their goals by using it.

There are other quality criteria, which I labeled as results rather than themes because they were based on statements made by fewer than half the students in the project. The ability to control the pace of the resource (result 7.a, page 189) was considered important because the students could consider certain aspects of a topic particularly hard and need to spend more time on it, while considering other aspects to be easier, requiring less time spent. The quality of explanations given (result 7.b, page 189) was mentioned by Andreas, Anna and Benjamin. Adrian and Christian mentioned breadth of functionalities as a reason they liked certain resources (result 7.c, page 189), while Adrian was the only student to mention appreciating resources that did not cost money (result 7.d, page 190). I think several of these quality criteria are likely to have significance to more students than the ones who mentioned them. Price in particular is likely to be important to the students who did not mention it. All the resources that students mentioned using were either emphasized in the course or available for free. Trouche and colleagues (2018) refers to free resources that are available to anyone as “open educational resources” or OERs. Based on my data, I consider it likely that very few university students would use non-emphasized, paid resources, but more likely for them to use OERs.

Another implicit quality criteria may be degree of familiarity. While students tend to only consider resources that they are familiar with, some resources may have become emphasized resources quite recently, so while the students use them, they are not very familiar with them. Result 5.2.a (page 182) details how three students expressed that they disliked certain digital resources. In all three cases, the resources were rather new to the students and they reported great difficulties figuring out what parameters the programs wanted or what syntax the program accepted.

In summary, when students make decisions about what resources to use, they consider resources they are familiar with from current or previous education, resources they have been recommended or search resources that they know from non-mathematical activities. They consider what resources are suitable for their goals and what resources they prefer using, and they evaluate the simplicity and efficiency of the resources in the context of a given set of goals. They may also consider the price of the resource, the quality of explanations, the breadth of functionalities and the extent to which they can control the pace of the information. The extent to which students use search resources may be influenced by their awareness of agency, which may in turn depend on the breadth of resources that are provided in the university course; the extent to which the course differs from secondary education and the extent to which university staff communicates the students' agency to them.

5.2.6 RQ6: Factors influencing resource use

In this subsection I address the sixth research question:

RQ6. Which factors influence the students use of resources?

Students' use of resources can be influenced in a variety of ways. Some factors may lead them to use certain documents more frequently for a period of time. Other factors may lead them to develop new documents or make significant changes to their document system. Some factors influence students' resource decisions, while other factors may also lead them to work more or less on mathematics in general. I will address this research question by looking at everything that, based on the data, influenced what resources the students, when they used them or to what extent they used them. Many factors will overlap with answers to previous research questions, at which point I will make an effort to curtail my discussion of them.

The course context, and particularly what resources are emphasized.

Several of the identified themes and subthemes concern students' reliance on emphasized resources. For what resources are emphasized in the different courses, see section 5.1.1 (page 194). Subtheme 1.2.1 (page 132) concerns students using emphasized resources when they experience ease; subtheme 4.1.1 (page 157) concerns students mainly using emphasized resources for introduction to a topic; subtheme 5.1.1 (page 178) concerns that when students have strategies with a plan A, plan B structure, emphasized resources tend to be plan A and themes 6.1 and 6.2 (page 185 and page 185) concerns that many of the resources that students use were discovered because they were emphasized in the course they currently attended or in previous education. The students may use these resources because they are emphasized in the socio-cultural context of the course or because they are efficient ways to learn. Either way, the students use emphasized resources more than they use non-emphasized resources. Resources that were highly emphasized in the courses were used particularly much by students. For instance, the courses did not emphasize textbooks very highly, and of the emphasized resources, textbook was the resource that the students expressed the least appreciation for (see subtheme 5.2.2, page 181).

Familiarity with the resources.

Result 5.2.a (page 182) concerns digital resources that were new to the students and that they did not appreciate. I theorize that more generally, students do not appreciate resources with a certain level of complexity until they are familiar with using them. Part of the reason for the extent to which students used emphasized resources, may be that they were used to such an extent within the course that students became quite familiar with them. That they used resources from secondary education (see theme 6.2, page 185) may also be taken as evidence of a preference for resources they were familiar with. Adrian used an example to make the point that he preferred resources that he was familiar with.

A1 And then, of course, to an extent how comfortable I am with it. It… (3.0) Abaci are both very practical and simple, but I have not used them, so then I will not use them either. (Adrian 1,7)

Features of the resources.

In part, students make their resource decisions based on preference and they have various quality criteria for resources. The themes within the theme category quality criteria (page 187) attest to appreciation for resources that are simple to use, can be quickly accessed and that can be used efficiently. When it comes to social resources, the extent to which they are easily available rely on the priorities of other people, which is the topic of result 1.c (page 137). The ability to control the pace of information when interacting with a resource; the quality of explanations provided by the resource; the breadth of functionalities and low price are also appreciated by students.

Which resources are used in combination.

Theme 1.3 (page 135) concerns that students use resources differently when they work with fellow students. In particular, they used digital resources less, text resources more and relied heavily on discussion with their fellow students (subtheme 1.3.1, page 136). This can be seen as the use of one particular resource influencing what other resources are used. As a second example of resources used in combination, Christian said that when he was already using his computer, he was likely to use Wolfram Alpha rather than the calculator.

C3 Calculator I have started using to a smaller degree, just because when I work I usually have the PC available, so I usually just use Wolfram Alpha as a calculator. (Christian 3,1)

Familiarity of the mathematical content or task.

Result 1.a (page 137) concerns some students mentioning that the familiarity of the mathematical content influenced how they used resources. In the case of Amalie, content that she was familiar with from secondary education led her to use her notebooks from secondary school. Celine found it particularly easy to use Google to find information relating to a familiar topic. Brage used the internet particularly much during the programming project because he was unfamiliar with the task and needed to look up information on how to use Maxima.

The experienced difficulty of the content or task.

Theme 1.2 (page 131) concerns that students mentioned difficulty as something that affected how they used resources. As described within subthemes 1.2.1 and 1.2.2 (starting on page 132), when the experienced difficulty is high, students use different resources than they normally do, and use non-emphasized resources and social resources to a greater extent. They may also be more likely to use resources for checking their answers, as expressed by the following statement from Adrian:

A1 When it comes to a bit more complicated things where you feel you have to double check, where it is not immediately obvious what is right, then it is – I do use more resources then (1.0) on simpler (0.5) topics. (Adrian 1,9)

The type of mathematical content or task.

As described related to result 1.d (page 138), students communicated that their use of resources did not vary much depending on the area of mathematics. However, a few students said that they used resources such as GeoGebra and Wolfram Alpha for geometry, or for content that the student would like a visual representation of.

The students' goals.

Theme 5.1 (page 176) concerns that students' resource decisions were primarily goal-based. They often communicated this by saying that they made decisions based on what was 'suitable' for the task at hand. The theme category didactical resource purposes (DRPs) also shed some lights on how students' process of learning is based on various goals. The introduction DRP (page 157) concerns goals of getting an overview of the mathematical content; practice (page 158) concerns goals of learning to complete mathematical tasks related to the content; evaluation (page 162) concerns goals of evaluating one's ability to complete said tasks and explanation (page 169) concern goals of finding specific information or improving one's understanding of specific aspects of the content. While a resource can be used for more than one DRP, students have different sets of resources for different goals. A student may, for instance, primarily use lectures for introduction, calculator for practice, Wolfram Alpha for evaluation and the textbook for explanation.

The amount of time available to the student.

Several aspects of students' university studies and their personal life are a higher priority to them than mathematics. Theme 8.1 (page 191) concerns mathematics being a low priority when students are short on time. Benjamin, in particular, talked about how his use of resources was affected by lack of time (see result 1.b, page 137). When he did not have much time, he used the textbook more than video lectures and he did not engage in practice very much. In his case, he did not have much time due to several factors besides the university, such as training and political participation. Other students mentioned engagement with other courses as a reason not to spend much time on mathematics. The topic of subtheme 8.1.1 (page 191) is that students often do not work on mathematics at all when they prepare for other exams.

At what point in the course students study, and in particular proximity to exams.

As discussed in subsection 5.2.4 (page 212), students develop their documents significantly at the start of a course, as they are faced with a new context. An aspect of the context that influences their development of documents may include a set of emphasized resources that differ considerably from what the students are used to. Students' documents are then updated quite quickly and are rather stable throughout the semester, unless they are faced with new situations that cause them to develop their documents. They may use resources differently when they work on mandatory assignments (subtheme 1.e, page 138). As mentioned in the previous paragraph, they tend not to work on mathematics at all when they prepare for other exams. When they prepare for their mathematics exam, they use resources differently, as is the topic of theme 1.1 (page 130). Specifically, subtheme 1.1.1 (page 130) concerns that students tend to emulate the exam situation when they prepare for exams. They solve problems from previous exam sets, and they tend to restrict their use of resources to resources that are allowed during the exams. For instance, they use the formula collection more and do not use digital resources. As discussed in subsection 5.2.4 (page 212), students may be more likely to reflect on their use of resources and decide on changes for the future during and after the exam preparation.

In summary, a great number of factors influence students' use of resources, ranging from features of the course context, to features of the resources and features of the mathematical contents. Some factors outside the educational context can also be influential, by limiting how much time students are able to spend on mathematics.

Chapter 6: Contribution to the field of research

In this chapter, I will first discuss how my research relates to the ideas within the field, that I identified in subsection 2.5.3 (page 36). I will discuss the degree to which I observed results similar to existing ideas, and what new ideas should be introduced based on my research. The most significant ideas that I want to introduce based on my research are related to my theory of didactical resource purposes. I also want to advocate that future research into students' use of resources contains an increased consideration of the degree to which various resources are emphasized within the courses. After this discussion of existing ideas and new ones, I discuss how these ideas help progress the field of research towards the goals of the field that I introduced in the first chapter (see figure 1.1, page 3). I then move on to discuss what I think a documentational approach to learning (DAL) should entail, based on my results. I also discuss important questions that ought to be investigated before such a theory could be viable.

6.1 Relation to ideas within the field

In this section, I discuss how my results relate to existing ideas within the field. I will divide the existing ideas into five areas of focus. Use and significance of social resources; use and significance of various resources; related to didactical resource purposes; resource decisions and types of learning. I also include a subsection for class of situations, which only consist of new ideas. While social resources could be incorporated into use and significance of various resources, I see social resources as an area of particular focus, and it is my impression that the same is true for many researchers within the field. I cover minor ideas 5 and 8 in both, since they involve both social resources and other resources. The use of various resources could be considered a result of resource decisions, but the ideas I label as tied to resource decisions are the ones I interpret as relating more closely to the reasoning behind the decisions. While I coin the term didactical resource purpose (DRP) in this thesis, I consider some of the existing ideas to be similar to individual DRPs and thus incorporate them into that section. Types of learning is here used to collectively refer to pragmatic versus epistemic focus and mediation and to procedural versus conceptual understanding. After discussing my research and existing ideas tied to each of those six areas, I will present an updated summary of ideas within the field in subsection 6.1.7 (page 251).

I need to make several clarifications about this updated list. Within the updated list of ideas, I will attempt to incorporate the results of other authors into my ideas as opposed to incorporating my ideas into existing ideas within the field. The reason for this is that it establishes a system of ideas that has a clear, logical structure. The downside is that the terminology is not always faithful to the articles of other authors. The wording of each idea within the upcoming summary of the field of research is my own interpretation. I will list articles by other authors as related to a given idea, even though I have phrased the idea using terminology that these authors did not use and that would not be appropriate within their paradigms. I do so, because I think the meaning of their original ideas (from a pragmatist interpretation of meaning as discussed in section 3.1, page 45) are similar to the meaning of the ideas that I have written down. I also believe that there are similarities between the data on which they based their interpretations and the data on which I based my ideas. Given their data, I might have interpreted it similar to how I interpreted my own data. Hence, the inclusion of other articles within an idea that I have included in the summary should not be seen as based on similarities in interpretation and terminology. Nor should one assume that the original authors would agree with my summary. Rather, it should be understood as communicating that *my interpretation* is that there is a similarity of meaning and of data between the articles that are listed as supporting the idea.

6.1.1 Use and significance of social resources

Within this subsection, I present my interpretation of existing ideas on the extent to which students use social resources and the importance that these resources have for the students. I will alternate between recalling one or more existing ideas (previously discussed in section 2.5.3, page 36) and discussing how my own research relates to said ideas. I do not address the existing ideas in numerical order, but rather in an order I think makes sense thematically. I begin with idea 18 addressing individual differences for the extent to which social resources are significant. Afterwards, I discuss idea 5, about extent of use, ideas 16 and 17 about significance and idea 12 comparing use of social resources from secondary to tertiary education. At the end, I list of my contribution, with new ideas relating to what resources are used in combination with social resources and general preference on group size.

Idea 18: Some students are more individually minded than other students. Individually minded students tend to see less benefit in working with students that are at a different level of mathematical skill than themselves. (Fredriksen et al., 2017)

Note that the terminology of individually minded students was not used by the authors of (Fredriksen et al., 2017). Nor was it a large focus of the article. However, I saw several indications for such a typology of students in my research. As discussed in subsection 5.2.2 (page 201), I interpret four of the students in my project to be individually minded, three to be socially minded and two to be a combination of both. One of the individually minded students, Casper, specifically mentioned that he had not worked much with others due to different levels of skill compared to the ones he would usually work with, similarly to the result of (Fredriksen et al., 2017).

Idea 5: Fellow students are used quite a lot, but at lower ranks. (Anastasikis, 2018)

It should be noted that the methodology of Anastasikis' project involved asking students for the five resources that they used the most. At lower ranks means that other students were more often mentioned as the students fourth or fifth most used resources than their top three. Specifically, the number of engineering students that mentioned other students as their first, second, third, fourth and fifth most used resource were 2.6%, 7.0%, 14.2%, 16.2% and 18.9%, respectively (Anastasikis, 2018, p. 95), so 58.9% of engineering students had other students as one of their five most used resources. It should be noted that the resources that students frequently listed within their top three most used resources in Anastasikis' project were generally ones that I would consider emphasized resources within the educational context.

In my project, I also found that fellow students were a resource that students used a lot, particularly those that were socially minded (see subsection 5.2.2, page 201). Just as Anastasikis, I found that emphasized resources were generally used more often than fellow students were. I think, if I had used the same methodology as Anastasikis, fellow students would only be among the two most used resources for Amalie and potentially Celine. It should be noted that the extent to which students used social resources compared to other resources is not necessarily an indication of how significant it is to them. Amalie and Andreas, for instance, mention that they learn better when they work with fellow students. However, for Andreas, fellow students would still not be high on his list of which resources he used the most.

The following ideas are based on work that focuses more on the resources' importance to the students, and how said importance developed over time.

> **Idea 16:** Over the course of the first year, students start seeing […] b) peers as more important […]. (Stadler et al., 2013)

> **Idea 17:** Besides working with peers, over the course of the first year, students start seeing every type of study activity as less important. (Stadler et al., 2013)

While my project only spans the first semester of students' studies (or third for University Beta), there were indications that the extent to which the socially minded students worked with fellow students increased over time. Students experienced the course to get gradually more difficult and said that they worked more with fellow students as a result (subtheme 1.2.2, page 134). While increased extent of use does not have to mean increased importance to the student, I think the indication that fellow students were used to overcome increased difficulty, implies that it was important to the students' success in the courses. This relates somewhat to idea 12.

> **Idea 12:** Students rely more on video resources and social resources at university than at secondary school. (Kock & Pepin, 2018)

The students in my project were not asked to discuss their use of resources at secondary school level, and few did so spontaneously. However, based on my research several students relied on fellow students when they experienced difficulty, and socially minded students relied on social resources more generally to learn.

In addition to the ideas above, my research can support some additional ideas about social resources:

- The resources that students use in combination with fellow students differ from the resources they use when they work alone
(theme 1.3, page 135)
- When students work with others, they use text resources more and digital resources less (subtheme 1.3.1, page 136)
- Students prefer to work in small groups, often consisting of three or four people including themselves (subtheme 2.2.1, page 147)

An interesting question for future study may be why students use certain resource more when they work with others. For instance, do they use the textbook more because it is emphasized; because it contains exercises or because it is easier to pass it around to show one's fellow students what one just read? Is it a combination of the above? Are there other reasons?

6.1.2 Use and significance of various resources

Many ideas related to university students' use of resources concern the extent to which students use various resources or consider various resources as important. In this subsection I group together similar ideas within that area and address how my research relates to the ideas. I begin with idea 1 about the extent of use of emphasized resources, then idea 4 that may be causally linked to idea 1. Next, idea 2 is about which non-emphasized resources are used, which leads into ideas 12 and 24 about video resources specifically. Back to emphasized resources, idea 6 concerns use of lectures and recordings thereof, and idea 3 concerns use of the textbook specifically, with some general aspects as well. Then ideas 15 and 16 may shed light on how the use of emphasized resources changes over time. Lastly, I cover three ideas that are not directly linked to emphasized resources. Idea 7 introduces a typology of resources and idea 8 introduces a typology of students, while idea 10 indicates that what type of student one is may depend on one's overall goals. My contribution to this category of ideas include focusing on the distinction between emphasized and non-emphasized resources, as well as new ideas that are discussed at the end of the subsection. These include students' rationale for using non-emphasized resources over emphasized resources; a shortage of emphasized resources used for evaluation and an idea about how students' use of resources changes over time.

> **Idea 1:** Students mostly use resources that are provided or otherwise emphasized in the course at hand, but to some extent they use external resources as well. (Anastasikis et al., 2017; Anastasikis, 2018; Kanwal, 2018)

That the students primarily focus on emphasized resources and have secondary strategies involving non-emphasized resources is evident from several themes I have identified, as I discuss in subsection 5.2.1 (page 198) and is among the most central results of my research. That students primarily use emphasized resources (and possibly use them more the stronger the emphasis on them is), may serve as an explain for the phenomenon described in idea 4:

> **Idea 4:** There is little variety to what resources students use the most, but greater variety in their lower ranked resources. (Anastasikis et al., 2017; Anastasikis, 2018)

It should be noted that the resources that students used the most in Anastasikis' study were emphasized resources. The number of resources that are heavily emphasized in a given course can be quite limited, so when students primarily use those resources, there will be little variety to the resources that students use the most. However, when looking beyond emphasized resources, there is a plethora of possible choices for other resources to use, and thus students choose differently. There are, however, some resources that are more commonly chosen than others. For instance, some are discussed within idea 2.

> **Idea 2:** The internet, online calculators, Wolfram Alpha and YouTube are among the resources that student use even if they are not emphasized in the course at hand. (Kanwal, 2018)

My results are quite similar to those of Kanwal. Wolfram Alpha and YouTube were among the more commonly used non-emphasized resources. My students mentioned the internet and often specifically mentioned Google as the resource they used to search the internet. While they did not mention online calculators, Christian did mention that when he worked on the computer, he used Wolfram Alpha instead of his calculator. GeoGebra and Khan Academy were also used by multiple students. It should be noted, that both Kanwal's research and my own took place within the Norwegian university context, so it is possible that this leads to a greater similarities in our results than it would if different national contexts were studied.

Ideas 12 and 24 relate specifically to video resources.

> **Idea 12:** Students use more video resources and social resources at university than at secondary school. (Kock & Pepin, 2018)

> **Idea 24:** When video resources are provided to students, they will also look for additional video resources on their own. (Borba et al., 2018)

My data on the students' experiences from secondary school is quite limited, so all I will say related to idea 12 is that students at University Beta and University Charlie used video resources quite a bit during their first university course. Related to idea 24, I made a similar observation based on students comments about resources they used for explanation. Out of the three students that mentioned using video lectures (which were emphasized video resources), all of them additionally used YouTube videos for explanation and one of them used Khan Academy. Those three students (Benjamin, Brage and Casper) all said that they used the videos to get an additional explanation of the mathematical content from a different source (subtheme 4.4.2, page 172). Of the remaining students, who did not use emphasized video resources, only Christian used YouTube for explanation. While he did not use them, he also attended a course in which video lectures were emphasized. I find this intriguing and think it is a good topic for further study. Critical reflection is a focus point within the Norwegian school system, and getting information from multiple sources may both be a good study habit and a good way to develop critical reflection. Considering that the four students mentioned above were quite successful students, one might theorize about the benefits of additional explanation in general and educational videos specifically.

Over to emphasized resources, but still related to videos, idea 6 related specifically to lectures and recordings of lectures. Note that these are different from 'video lectures'. For clarification, read the descriptions in appendix J of 'lecture streaming/videos' (page 403) and 'video lectures' (page 406).

> **Idea 6:** Students have different preferences between attending lectures and watching recorded lectures, and some switch which one they focus on in the middle of a course. (Howard et al., 2019)

Within my project, University Alpha provided recorded lectures, while University Charlie provided recorded plenary sessions. Considering I recruited students to my project during lectures, my sampling was biased in favor of people who attend lectures. None of the students in my project from University Alpha relied on recorded lectures from the start of the semester. However, Andreas is an example of a student who switched focus from physical attendance to watching recordings midway through the first semester. At University Charlie, Celine mostly used the recordings of the plenary sessions while Casper and Christian chose to attend the plenary sessions.

The next idea concerns a factor that may influence the extent to which students use resources in general, and the textbook specifically:

> **Idea 3:** Students use the textbook and other resources more if they are tied specifically to the course at hand. (Kock & Pepin, 2018)

This is an interesting aspect of the topic of emphasized resources. As I discuss at the end of subsection 5.2.1 (page 198), there are multiple possible reasons why students focus on emphasized resources. One of them, is that they are efficient, because they provide information that the course organizer has indicated is relevant to the course at hand. A textbook created specifically for the course is particularly relevant to said course. Hence, given that interpretation, it makes a lot of sense for students to prefer such a textbook over a textbook made for a somewhat similar course at a different university. A textbook made for a course at a university in a different country may be considerably less relevant and thus less efficient. Within my project, I cannot compare between universities using highly specific and less specific textbooks. Each university in my project used American textbooks. Several students use the textbook for introduction, and most used it as a source of exercises. However, the textbook was the resource that the most students voiced their frustration with (see subtheme 5.2.2, page 181), and everyone had resources that were more central to them than the textbook. Regarding resources that were made specifically for the courses, the lecturer at University Alpha provided his lecture notes, which was hardly used by students.

Andreas may have used it during the exam preparation, when he filled in "notes" as a resource for a study session, but he may also have referred to his own notes. The lecturer at University Beta, however, provided video lectures, which were used quite a lot, particularly by Benjamin. Overall, I would say that my data provides more evidence to support the idea than to contradict it, but there is a lot of evidence on either side.

Partially related to emphasized and non-emphasized resources, it is interesting that Stadler and colleagues found that, over time, students started considering several non-emphasized resources to be more important and a few of the emphasized resources less important:

> **Idea 15:** Over the course of the first year, students a) start using the teacher less, b) start using internet-based resources more, and c) start using social resources more. (Stadler et al., 2013)

> **Idea 16:** Over the course of the first year, students start seeing a) previous tests as more important, b) peers as more important, c) computer calculation as more important, d) internet-based resources as more important, e) formula books as less important, and f) calculators as less important. (Stadler et al., 2013)

Since my project only spanned one semester and did not have a quantitatively significant sample, I am unlikely to see as clear changes as Stadler and colleagues. However, within my study, I did find that when students experienced an increase in difficulty, they used social resources and non-emphasized resources more. If the difficulty keeps increasing throughout students' second semester (which seems likely), this might be a reason for Stadler's findings. The exam period led to students using previous exam sets more. Christian, in particular, expressed that he focused more on previous exam sets than he had originally planned. Anna and Celine talked about their plans for the second semester. Celine said that she would use student assistants more during her second semester. Contrary to the results of Stadler and colleagues, Anna said that she would use the formula collection more because the exam period had convinced her of its importance.

Among the foci of Anastasikis' doctoral thesis were the goals to statistically identify typologies of resources based on which resources were often used in combination and typologies on students based on how much they used various types of resources. The results are summed up in the following ideas:

> **Idea 7:** Students' resources mostly fit within the five categories of peers, teachers, external online tools, the official textbook and students' notes. (Anastasikis, 2018)
>
> **Idea 8:** Students mostly fit within the five profiles of the peer-learning, the online-learning group, the blended-learning group, the predominantly textbook-learning group and the selective-learning group. (Anastasikis, 2018)
>
> **Idea 10:** The type of goals a student has influences which learning profile they correspond to. (Anastasikis, 2018)

Whether or not these results were intended to be generalized beyond the institution that was researched, I think it is worth considering whether they could be. I will try to apply these ideas for the resources reported and the students within my project, to see how well these typologies can be applied to my data. I look at all the resources in Appendix J (page 401) apart from a) for redundancy, the specific calculator and formula collection mentioned by Adrian are grouped with 'calculator' and 'formula collections'; b) internet and videos are ignored for vagueness; c) resources that were mentioned, but never used by students are ignored and d) the resources that were only mentioned in one study session filled into the Studert app are ignored. I try to fit each resource or resource category into Anastasikis' typology. I label the ones that do not fit as 'none of the above'. It is important to note that within the categories by Anastasikis, are included "secondary artefacts" (with reference to Wartofsky) related to the actions one performs using the resource that the category is named after. For instance, phone is a secondary artefact related to peers, because the student who mentioned his phone (Brage) used it in order to communicate with peers. Therefore, I also write the action that Anastasikis relates to each category in parenthesis (Anastasikis 2018, p. 108).

Peers (interacting with peers): Fellow students, group sessions, interactive lecture, math lab, phone, student assistants.

Teachers (interacting with teachers or support staff): E-mail, interactive lecture, lecture, lecture streaming/videos, lecturer, lecturer's notes, overview lecture, plenary.
External online tools (searching for additional/alternative sources of information): Google, Khan Academy, YouTube.
The official textbook (studying the official mathematics textbook): Exercises, recommended exercises, textbook, solution suggestion.
Students' notes (taking notes during a lecture): lecture notes, pencil & paper.
None of the above: Calculator, Canvas, course page/math wiki, exam sheet, formula collection, GeoGebra, Maple TA, Maxima, Mediasite, MyMathLabs, parent, previous exam sets, ring folder, screenshots, simulations, SimReal, Studert, video lectures, windows & marker, Wolfram Alpha.

Organized sessions to facilitate interaction between teachers and students are secondary resources within the category teachers. While student assistants appears to be in a grey area, I have chosen to categorize them as peers rather than support staff. In total, I was able to categorize 22 out of 42 resources within Anastasikis' system. I will now address why I found some resources or resource categories hard to label within the typology. I think the naming of external online resources is a bit confusing. I would not, for instance, refer to resources such as video lectures, MyMathLabs, Canvas, etc. as *external* online tools, considering that they are emphasized in the courses in which they are used. The descriptions of activity also appear to focus exclusively on introduction and explanation and not take into account practice and evaluation. Thus, even though I would call GeoGebra and Wolfram Alpha external online tools, I do not think the activity "searching for additional/alternative sources of information" is an accurate way to describe how students interaction with these resources, even though Anastasikis himself labels Wolfram Alpha as an external online tool.

I whole-heartedly agree with Anastasikis that categorization of resources ought to be viewed in terms of how they are used in combination (though from my theoretical standpoint I would focus on goals rather than activity), and I think his system could be refined in order to make it more broadly applicable to university context beyond the one it was made based on, by adding categories and redefining existing categories.

Moving on to student profiles (Anastasikis, 2018), I will try to classify the students who participated in my project. For more information on my interpretation of said profiles, see page 30.

Adrian: If any of the groups fit him, it is the predominantly textbook-learning group, but he does not seem like a typical member of said group. Adrian does have several digital resources as part of his strategies, but he does not use them much, nor does he use many social resources (see subsection 4.2.1, page 98). Based on his use of resources, he fits the group, but based on his strategies, it is more difficult.

Amalie: Peer-learning group. Amalie reportedly worked with fellow students quite a lot (presumably more than average) and with the textbook and online resources to some extent (presumably less than average). As such, she appears to fit within the peer-learning group (Anastasikis, 2018)

Andreas: Based on the interview, it seems that Andreas strategies would place him in the peer-learning group, but based on practical difficulties he was unable to work with fellow students as much as he wanted. Instead, he used the textbook and the lectures or video streams (see subsection 4.2.3, page 102), which might mean he fits better in the selective-learning group.

Anna: Blended-learning group. The blended-learning group consist of students who used every category of resources more than average. Anna worked a lot on mathematics, using the lectures, notes, fellow students and online resources. While students from University Beta and University Charlie possibly used digital resources more than her, I think Anna used digital resources more than the average student at University Alpha.

Benjamin: Blended-learning group appears to fit his strategies the best. Benjamin seemed to want to use a great variety of resources: MyMathLabs, textbook, lectures, lecturer, notes, fellow students, simulations and videos (see subsection 4.2.5, page 107). In practice, however, he used MyMathLabs and fellow students very little due to lack of time, making his actual use difficult to categorize.

Brage: Online-learning group. MyMathLabs appeared to be the resource that was the most important to Brage and that he used the most (see subsection 4.2.6, page 110). Video lectures were also central to him.

Casper: None of the above. Casper is hard to place within Anastasikis' system. He seemed to use teacher-resources and online resources more than average and the textbook and peer-resources less. Compared to the online-learning group he uses teacher-resources too much, while no other group features students who use both the textbook and peer-resources less than average.

Celine: Blended-learning group. Celine works on mathematics for many hours a week (compared to Casper and Christian), utilizing a wide range of resources, including organized sessions, fellow students, textbook, Google, Wolfram Alpha and her own notes.

Christian: Blended-learning group. Christian used a great variety of resources within all the categories of the textbook, peer-resources, teacher-resources, online resources and own notes.

Now I will address whether my research supports Anastasikis' notions of relationships between students' goals and what profiles they fit into. Anastasikis (2018, p. 119) found that students mostly concerned with passing the course were more likely to fall within the peer-learning group; students who wanted to learn mathematical skills were more likely to fall within the blended-learning group; students oriented towards opening their mind were more likely to fall within the selective learning group and students oriented towards understanding mathematical theory were more likely to fall within the predominantly textbook-learning group.

There is not much evidence either way within my project. Students in my project mostly referred to sub-goals like solving specific exercises or finding specific information rather than over-arching goals. However, textbook was mentioned as something students used for the sub-goal of learning the theory (see theme 4.1, page 157).

In general, the student profiles are an easy way to categorize students. I also think they are an intriguing avenue of future research. Further understanding why student end up in one of the profiles might help improve the description of the profiles to make it more applicable to other contexts. For instance, I think the textbook was more highly appreciated in the university context that Anastasikis studied than in the ones I did, which may have led to some of the difficulties of categorizing students. I also think future research could answer questions such as relationship between student profile and performance, both in the short term (grades achieved) and in the long term (job-relevant skills developed). For instance, do peer-learning students perform worse than other students? If so, do they perform worse because of the lack of flexibility of their studying strategies? Does the blended-learning group outperform the other groups, and if so by how much? Research on these questions may help instructors guide students towards fruitful learning goals and strategies.

Beyond the ideas mentioned, I think my research can support the following ideas about the use and significance of various resources:

- Students change their resource strategies quickly in response to changes within the context and quickly reach stable strategies.
- Students' motivations to use non-emphasized resources include wanting additional explanations, not being able to achieve their goals using the emphasized resources and not having emphasized resources for their goals.
- Few emphasized resources aid students' goals related to evaluating themselves or their solution of specific exercises.

6.1.3 Related to didactical resource purposes

Some ideas within the field relate closely to what I have chosen to call didactical resource purposes (DRPs). I would argue that while DRPs are new theoretical constructs that I am introducing, they can be a good framework with which these existing ideas can be interpreted, and additional ideas can be explored. I will first consider ideas related to introduction, then ideas related to practice and evaluation, then ideas related to explanation and lastly an idea related to the order in which resources are used. My main contribution to this category of ideas, is to introduce the theory and the term didactical resource purposes. I introduce a simple way to represent resource use in a table based in DRPs. In addition, I introduce ideas related to what resources they use and the degree to which emphasized and non-emphasized resources are used tied to specific DRPs. At what point during their studies students use evaluation is also the topic of one new idea.

I think Kock and Pepin's use of the term starting point is quite similar to the DRP introduction.

> **Idea 20:** Students often use the lecture as a "starting point"
> (Kock & Pepin, 2018)

To clarify what they meant by that statement, the authors write that the lectures "provided an orientation on the subject […] and to some extent an enculturation into the world of mathematical concepts and their usages." (Kock & Pepin, 2018, p. 340). The path from not knowing anything about a topic to a base understanding of the mathematical objects and terms involved is central to the idea of introduction as a DRP.

In my research, lectures was the resource that was the most commonly used for introduction, ahead of the textbook. Three students did not use lectures for introduction, however. Andreas did not specifically mention resources for introduction, Amalie only mentioned the textbook and Brage only mentioned the video lectures. I think lectures are used for introduction by many students at many different universities, but there may be differences between university contexts. Brage's reliance on video lectures may be because he attended a previous course with Bjørnsen as the organizer, in which there were no lectures, and the course emphasized video lectures for introduction. I think a more general idea, which I expressed in subtheme 4.1.1 (page 157), is that students mostly use emphasized resources for introduction.

Next, an idea that I would relate to the DRPs practice and evaluation:

> **Idea 21:** Tests and exercises are used to assess one's own understanding.
> (Kock & Pepin, 2018)

This idea seems to represent a similar perspective to the one expressed by Amalie.

A2 And then I learn through doing exercises, that is sitting and doing more exercises and find out what – the stuff I do wrong and (1.0) how I should do them. (Amalie 1,2)

My results indicate that students work a lot on exercises and consider them important. Few statements by students go into why, and those that do usually refer to the exams. However, I do believe that idea 21 can provide a good explanation for observed resource use, and I think it is an interesting topic for future study. Within ideas about types of learning (subsection 6.1.5, page 246), many of them relate to solving exercises and the extent to which students consider it important, which in turn relate to the DRP practice. For evaluation, however, it appears to be of little focus among researchers, compared to how much emphasis students within my project places on it. I think this is the greatest gaps between previous research and students' experiences that my data can help identify.

I would relate the following two ideas to the DRP explanation:

Idea 22: Students tend to use video resources to get an additional explanation. (Kock & Pepin, 2018)

Idea 23: Students tend to use YouTube, Facebook and Google for "help-seeking". (Puga & Aguilar, 2014)

That students use several resources to get an additional explanation is the topic of subtheme 4.4.2 (page 172), and YouTube is the resource that the most students used for this purpose. Puga and Aguilar's use of the term help-seeking stem from social psychology and they clarify that it should be interpreted as a useful skill to overcome problems, rather than as a symptom of lack of competence (Puga & Aguilar, 2014). I believe my use of the DRP explanation is quite similar. YouTube and Google were among the most common resources for explanation. Puga and Aguilar focused exclusively on non-emphasized online resources. Like in their study, students within my project used YouTube and Google a lot for explanation. However, none of the students in my study mentioned using Facebook. This may be a coincidence of sampling, but based on personal experience, I think it is more likely to be a difference between the Norwegian and the Mexican school contexts.

The next result concerns the order in which students use resources.

Idea 19: Study paths (which resources were used in which order) may be a fruitful way to investigate students' use of resources. (Pepin & Kock, 2019)

Study paths concern the chronological order in which students use resources. It can be used to describe the overall strategies of students. It can be applied to the students within my project. For instance, if we look at Casper's schematic representation of resource system (page 114 or 419), ignore pencil & paper and assume that new curriculum is followed by practice and then repetition, his study path appears to be Textbook → Overview lecture → Interactive lecture → Recommended exercises → Wolfram Alpha → Plenary → Khan Academy/YouTube. There is some difficulty representing that Casper goes back and forth between exercises and Wolfram Alpha, but otherwise it seems likely to represent his study path. While this is a quick way to summarize Casper's use of resources, I think the idea of DRPs expands upon study paths to describe why the resources are used in that order through discussion of the purposes that the students use the resources for. I would argue that the model of didactical resource purposes could summarize a student's use of resources that is nearly as simple and offers more insight into their resource use. I propose summarizing Casper's use of resources the way I do in table 6.1. Within it, I categorize the resources depending on the type of DRP that they are used for. I have derived based on his statements that Wolfram Alpha and plenary session are used for evaluation.

Casper's use of resources for mathematics	
Introduction	Textbook, overview lecture
Practice	Interactive lecture, recommended exercises, pencil & paper
Evaluation	Wolfram Alpha, plenary session
Explanation	Khan Academy, YouTube

Table 6.1: What resources Casper used for each didactical resource purpose (based primarily on his mind map).

In the event that students have strategies with a plan A, plan B structure, they could be incorporated into the model as well, featuring a column for each. Resources used for introduction could be put in the introduction, plan B field.

Looking beyond Casper's SRRS to everything he mentioned in the interviews, his use of resources may be summed up like in table 6.2.

Casper's use of resources for mathematics		
DRP	Plan A resource(s)	Plan B resource(s)
Introduction	Math wiki, textbook, overview lecture	Google
Practice	Interactive lecture, recommended exercises, math lab, pencil & paper	Wolfram Alpha, video lectures
Evaluation	Wolfram Alpha, plenary session	
Explanation	Math wiki, Khan Academy, YouTube	Repetition videos

Table 6.2: What resources Casper used for each didactical resource purpose and as plan A and plan B resources (based on the interviews).

I think using DRP tables to summarize students' use of resources could be useful for future studies about students' resource use as a whole.

Related to didactical resource purposes, I think the following ideas could be introduced to the field of research:

- For a given class of situation, students learn new topics through the phases introduction, practice, evaluation and explanation.
- Students tend to use emphasized resources for introduction.
- Students tend to use emphasized resources as plan A for practice and use more non-emphasized resources as plan B.
- The main strategies for evaluation include using social resources, checking answers through the source of the exercises and finding the answer with digital calculation tools.
- Students rarely (but sometimes) evaluate their work process.
- Evaluation of the work process is more likely to occur during the exam period or between courses.

- The videos, channels and websites that students find through search resources like Google and YouTube are mostly just utilized. Students rarely start using them frequently.

6.1.4 Resource decisions and guidance

All students' interactions with resources can be said to be a result of their choices, and choices are often made with other people's recommendations in mind. The guidance that teachers give to student can vary from making the use of a resource mandatory, to hardly giving any recommendations. Ideas 13 and 14 deal with the level of guidance that lecturers at universities give to students and how they relate to students' use of resources, while idea 11 seems appropriate to address in combination with idea 13. In this subsection, I discuss how the results within my project relate to those three ideas. I also introduce new ideas that students choose from a pool of resources that they are familiar with, based primarily on the task and secondarily on preference. I also introduce ideas about the degree to which students get recommendations from lecturers and fellow student and base their decisions on those recommendations; what quality criteria students judge resources by and which resources they are familiar with from non-educational contexts.

The three existing ideas to be discussed are:

> **Idea 11:** Students' use of resources at the start of University is greatly influenced by their secondary school experiences, but changes as they encounter the university context. (Stadler et al., 2013; Gueudet & Pepin, 2016; Kock & Pepin, 2018)
>
> **Idea 13:** Students tend to have less guidance tied to the use of resources at University compared to secondary school and find it harder to make choices. (Gueudet & Pepin, 2016; Kock & Pepin, 2018)
>
> **Idea 14:** The less guidance the lecturer gives, the more varied students' use of resources is. (Kock & Pepin, 2018)

While comparison to secondary school was not originally a focus in my project, some students did spontaneously speak about how they worked at secondary school, and they had made changes since then (theme 3.2, page 152). The changes did, however, seem to have happened rather quickly at the start of the semester. Students at University Alpha may have changed their resource use the least from secondary school. It is my impression that University Alpha was the most similar to students' experiences from secondary school. The fact that weekly exercises were referred to as 'homework' contributes to this impression and is in stark contrast to the 'recommended exercises' at University Charlie. The latter communicates more agency to the students, while homework is associated with mandatory tasks.

I would say that Andersen provided rather clear guidance, and did not make an effort to communicate students' agency to them beyond the option to view videos of lectures rather than physical attendance. At University Charlie, the lecturers communicated more agency, while the organization of the course still provided a clear recommendation. The organized sessions had a rather clear introduction-practice-evaluation structure, with the overview lectures focusing on introduction to the theory, the interactive lectures and math labs focusing on solving exercises and the plenary sessions focusing on the answers for recommended exercises that students were presumed to have worked on during the week. Bjørnsen made many resources available online and specifically said in the interview "Like I tell my students… (2.0) It is organized with a lot of freedom". University Beta appeared to have multiple recommendation for resources to use, providing the least guidance of the three universities.

While all the students in my project primarily used emphasized resources, the students from University Beta differed the most in terms of what emphasized resources they focused on. Brage primarily focused on MyMathLabs, while also using lectures and video lectures. Benjamin primarily focused on the video lectures and the textbook, while also using the lectures, simulations and eventually MyMathLabs. At University Alpha and University Charlie, students seemed to use the emphasized resources in similar ways to the recommendations within the courses. However, there were differences between the non-emphasized resources that students at the two universities used.

At University Alpha, the non-emphasized resources (not counting fellow students), included Wolfram Alpha, Google, GeoGebra, old notebooks from upper secondary and parent. The first three were mentioned by multiple students, but not used much, while the last two were only used by Amalie. At University

Alpha, the non-emphasized resources included Wolfram Alpha, Google, YouTube, Khan Academy and GeoGebra. The first four were mentioned by multiple students, while only Celine mentioned the last one. Students at University Alpha used more resources that they may have used at secondary school (GeoGebra, old notebooks and parent), while students at University Charlie relied more on video resources (YouTube, Khan Academy).

None of the students in my study stated that they had any difficulty making decisions regarding resources. The students at universities Beta and Charlie, who experienced more agency, all arrived at resource strategies that were successful, in that they performed well in the courses. If students found it harder to make choices, they did not spontaneously talk about it in the interviews.

In summary, related to idea 11, my data supports that students based their resource use on their experiences from secondary, but update them for tertiary education. The extent of the update depends on how different from upper secondary school the university course appears to be. Related to idea 13, there appeared to be less guidance than at secondary school, but the extent of the difference varied. I do not have data to support the idea that students have a hard time making decisions. Related to idea 14, my data is consistent with a larger degree of variance between the resource strategies of students within courses with a smaller degree of guidance.

While I have no new ideas to add related to guidance, I think an interesting question for further study is whether there is a correlation between level of guidance and performance. My impression is that ‘conventional wisdom’ within the field of research assumes that there would be a positive correlation, and that students would arrive at more effective strategies the more guidance they get from instructors. However, if anything, the opposite is the case for the students and universities within my project. The course at University Alpha provides the clearest guidance to students and has the most negatively skewed grade distribution, while University Beta has the least guidance and the most positively skewed grade distribution. While I am not bold enough to theorize a negative correlation between guidance and performance based on a sample of only three courses, I think many students are capable of arriving at successful strategies on their own.

Related to resource decisions (focused on the students, not on guidance), I propose the following new ideas:

- When making resource decisions, students may exclusively consider resources they are familiar with through current or previous education, recommendations or non-mathematical uses.
- Students primarily make their resource decisions based on what resources they consider suitable for the task and secondarily based on personal preference.
- Students' perception of suitable resources is affected by the organization of the course. They often use emphasized resources first and only use non-emphasized resources if they are unable to achieve their goals using the emphasized resources.
- Students primary quality criteria include simplicity and the ability to use the resources efficiently. Other criteria include price, breadth of functionality, quality of explanations and ability to control the pace of information.
- Students often recommend Wolfram Alpha to one another.
- Google and YouTube are among the most commonly used resources that students are familiar with from non-mathematical uses.

6.1.5 Types of learning

The theories of epistemic versus pragmatic techniques and conceptual versus procedural understanding, both deal with two types of learning. The epistemic mediation with resources is more focused on organizing ones understanding, than pragmatic mediation, which puts the understanding to use. Conceptual knowledge is more fundamental and abstract, and can make the student more flexible and capable to adapt to new situations. Procedural knowledge is more situation-specific and can help the student solve familiar problems faster and more consistently. Whether explicitly stated or not, the use of these theories are commonly associated with a concern that students who are motivated by assessment may be overly concerned with the quicker types of learning, rather than the more flexible, fundamental types of learning. This focus is theorized to hurt their performance in the long term. Hence, goals are also central to looking into types of learning.

Within this section I will alternate between recalling ideas within the field and discussing them in light of my own research. I will start with idea 27, concerning the focus of university courses compared to secondary education. Then I will discuss idea 28 on the type of learning that textbooks focus on. Next, the type of learning that students focus on is the topic of ideas 9, 25 and 26. Lastly, ideas 29 and 30 concerns how certain tasks may promote certain types of learning.

First, the idea regarding differences in focus between secondary education and university courses:

> **Idea 27:** Compared to secondary school, university mathematics a) is more difficult, and b) has a more conceptual focus. (Kock & Pepin, 2018; Furinghetti et al., 2013; Breen et al., 2013)

That most of the students found university mathematics to grow increasingly difficult through the course of the first semester, is quite evident in my project (see theme 1.2, page 131). Related to conceptual versus procedural focus, Andersen appears to be focused on exercises and examples and expresses that he has such a focus because it is the students' first year. This may communicate that he wants to ease students into the conceptual focus of the university by starting with a rather procedural focus. Bjørnsen focuses on clarifying to students what is important. According to Benjamin, the first video lectures on a topic focus on understanding, while the remaining videos focus on examples. Benjamin also describes the exam as focused on understanding. I believe Benjamin's use of the term understanding relates to conceptual, rather than procedural knowledge. The organization of the course at university Charlie implies a large focus on doing exercises. However, I think Christensen's comment that he wants lecturers to have a lot of time with students to see what they struggle with and identify their misconception speaks to a concern for the students' conceptual understanding as well. In summary, University Alpha appears to focus on procedural understanding (at least during the first year), University Charlie appears to primarily focus on procedural understanding, while at University Beta, the focus appears to be rather balanced. I do not have a basis to compare the focus at the different courses to secondary education.

Next, the idea about textbooks.

> **Idea 28:** Engineering textbooks at the start of University mostly focuses on procedural knowledge. (Randahl & Grevholm, 2010)

The students in the project did not generally describe their textbook very much. When they did, it was generally through statements about the degree to which it was easy to read. Benjamin said that the textbook explained quite well where values came from, but it is not clear whether this refers to general relationships that can be classified as conceptual understanding.

Next, it is worth looking into ideas about the students' foci, related to types of learning.

> **Idea 9:** Students' goals regarding their use of resources in mathematics are mostly tied to assessment. Understanding is also a significant goal. (Anastasikis et al., 2017; Anastasikis, 2018; Howard et al., 2019; Kock & Pepin, 2018)

> **Idea 25:** First year students tend to focus on the pragmatic rather than the epistemic value of resource-mediation. (Gueudet & Pepin, 2016; Kanwal, 2018)

> **Idea 26:** Students appreciate both conceptual and procedural tasks. (Breen et al., 2013)

The students in my project who spontaneously talked about their goals related to assessment, did so when they talked about doing exercises. Adrian said that while the exercises were not mandatory, he would argue that they were mandatory if one wanted to do well in the course. Christian expressed his views even more clearly:

C3 The textbook I think is quite nice, and then I think doing exercises is essential. That stems from math being a repetition course and if you do not do exercises you are *fucked* at exams. And you will not learn either, if you do not do exercises, so… yeah. (Christian 1,6)

Benjamin expressed that doing exercises was not necessary to "understand it", but they were necessary in order to be "good at it", so he used exercises a lot more when preparing for exams. That students tended to emulate the exam situation when they prepared for exams (subtheme 1.1.1, page 130), may be seen as an indication of a pragmatic/procedural focus because they learned techniques and strategies very specific to the context of the exam. The extent to which students increased their time spent on mathematics leading up to the exam, seems to be a clear indication that they were motivated by assessment.

Result 8.a (page 192) also indicates that to some degree, students focused on understanding. Of the students, Benjamin seemed to be the only one to express his thoughts on understanding in a way that clearly indicated a focus on conceptual understanding, both due to the number of times he talked about understanding, and that it clearly did not refer to exercises. For instance, he expressed his strategy to focus on understanding throughout the year and on exercises leading up to exams. He said he learned from explaining to others and felt like it improved his understanding of things. When asked about difficulty, he also said the following

B1 For my part I think I (1.5) If I get a good explanation, I think most things are easy. […] Er, it is just about having a bit of a base for, er… what is underneath, and then… get an explanation for (1.5) how it is derived, and then I think most things are alright (Benjamin 1,6)

In summary, while all the students found it important to solve exercises, only one strongly indicated the importance of developing understanding of mathematical objects and relationships. My results are thus very much in line with ideas 9 and 25. Since my project does not focus on tasks, it does not have a lot of potential to support or contradict idea 26.

Lastly, some ideas are about types of tasks that have the potential to promote certain types of learning.

Idea 29: Visual tasks can help facilitate conceptual understanding of integrals. (Hoffkamp, 2011; Swidan & Yerushalmy, 2014)

Idea 30: Experimental tasks in dynamic geometry environments can help facilitate conceptual understanding of geometric objects. (Leung et al., 2013)

Both these ideas hints at a potential causal link between task and understanding. I will not make any claims about causality based on my research. I will note, that of the people who used GeoGebra, the student with the most conceptual focus appeared to use it to explore mathematical objects and relationships. Benjamin used sliders in GeoGebra to explore the relationship between the parameters and the shape of the graph (see subsection 4.2.5, page 107). Adrian and Celine, on the other hand, used GeoGebra to check their answers and locate the source of errors (see quotes by them to theme 2.1, page 141). The goals behind Adrian's and Celine's use of GeoGebra appear to be more procedural. There is still the possibility that the interaction with GeoGebra has conceptual value, even if the students have a procedural focus, which I consider an interesting topic for future research. I would add as an idea that:

- A conceptual focus from the student may be a pre-requisite for interaction with dynamic geometry software to result in development of conceptual understanding.

6.1.6 Classes of situations

Given the shortage of research projects using the documentational approach to investigate students' use of resources, there are (to my knowledge) no ideas in the field regarding classes of situations. Hence, it is made up entirely of new ideas that I think could be important to the field of research. Related to the theme category classes of situations (subsection 4.4.1, page 155), I would like to propose the following results (in addition to the one about working with others, described in subsection 6.1.1, page 226):

- Students develop documents for wide, general classes of situations.
- Students have a "prime document" with resource strategies that they use to learn new mathematical content under circumstances that they consider sufficiently normal.
- Students use resources differently when preparing for exams.
- Students use resources differently depending on the level of difficulty they experience.
- Several factors may affect students' use of resources, such as the area of mathematics being studied, the degree of familiarity, the time available to

the students, the availability of social resources and whether they are working on mandatory assignments.

- When students prepare for exams, they tend to emulate the exam situation by solving problems from previous exam sets and using only resources that are allowed at exams.
- When students experience difficulty, they tend to use more non-emphasized resources and work more with fellow students.

6.1.7 Updated summary of the field of research

In this section, I will make a list of ideas within the field, similar to what I did in subsection 2.5.3 (page 36), but focusing more on my own results and interpretations. I will revise some existing results, to fit within my terminology and to fit better with my results and interpretations. Hence, it should be noted that when I make references to other articles and papers for an idea, they may not use the same terminology and the idea may be a combination of their ideas and my own.

Given that I have chosen the literature selectively based on my results, the summary is for the field of research that is relevant to the holistic focus of my research. It is not a complete summary of research into university students' use of resources to learn mathematics. Such a summary would need to include many other foci, such as the affordances of various specific resources, student identities, discourse and an increased emphasis on instructors' guidance. Instead, this summary is a good summary of the results in my project and my interpretation thereof. It also includes ideas that my project do not provide evidence for, due to its research foci, but that I think would be relevant to future research projects with foci that only slightly differ from my own.

I summarize the ideas in table 6.3. I will give the ideas new names and order them based on the topic as I have previously in this section. I will write "hoc loco" (latin: in this place/passage) to refer to this thesis when it either introduces an idea or provides evidence to support an idea.

Use and significance of social resources		
Idea USS.1	Some students are more individually minded (learns better from working alone), some are more socially minded and some are a combination of the two. Individually minded students tend to see less benefit in working with students that are at a different level of mathematical skill than themselves.	(Fredriksen et al., 2017; Hoc loco)
Idea USS.2	Fellow students are used quite a lot, but are rarely among students' two most used resources.	(Anastasikis, 2018; Hoc loco)
Idea USS.3	Over the course of the first year, students start seeing peers as more important. Increased difficulty may be one factor contributing to this change.	(Stadler et al., 2013; Hoc loco)
Idea USS.4	Besides working with peers, over the course of the first year, students start seeing every type of study activity as less important.	(Stadler et al., 2013)
Idea USS.5	Students rely more on social resources at university than at secondary school.	(Kock & Pepin, 2018; Gueudet & Pepin, 2018)
Idea USS.6 (and COS.5)	The resources that students use in combination with fellow students differ from the resources they use when they work alone. They tend to use text resources more and digital resources less when they work with others.	(Hoc loco)
Idea USS.7	Students ask fellow students for help before they ask the lecturer.	(Gueudet & Pepin, 2018; Robinson et al., 2015; Hoc loco)
Idea USS.8	Students prefer to work in small groups, often consisting of three or four people, including themselves.	(Hoc loco)

Idea USS.9	Students get a lot of help from fellow student when experiencing difficulty.	(Kock & Pepin, 2018; Gueudet & Pepin, 2018; Ragual & Ogena, 2012; Hoc loco)
Use and significance of various resources		
Idea USV.1	Students mostly use resources that are provided or otherwise emphasized in the course at hand, but to some extent they use external resources as well. The more heavily a resource is emphasized in the course, the more likely students are to use them.	(Anastasikis et al., 2017; Anastasikis, 2018; Kanwal, 2018; Hoc loco)
Idea USV.2	Within a course, there is little variety to what resources students use the most, as they are primarily emphasized resources. There is greater variety among the rest of the resources used.	(Anastasikis et al., 2017; Anastasikis, 2018; Hoc loco)
Idea USV.3	Commonly used non-emphasized resources include the internet, Google, online calculators, Wolfram Alpha, GeoGebra, Khan Academy, Facebook and YouTube.	(Kanwal, 2018; Puga & Aguilar, 2014; Hoc loco)
Idea USV.4	Students' motivations to use non-emphasized resources include wanting additional explanations, not being able to achieve their goals using the emphasized resources and not having emphasized resources for said goals.	(Hoc loco)
Idea USV.5	Few emphasized resources aid students' goals related to evaluating themselves or their solution of specific exercises.	(Hoc loco)
Idea USV.6	Students use more video resources at university than at secondary school.	(Kock & Pepin, 2018)

Idea USV.7	When video resources are provided to students, they will also look for additional video resources on their own.	(Borba et al., 2018; Hoc loco)
Idea USV.8	Students have different preferences between attending lectures and watching recorded lectures, and some switch which one they focus on in the middle of a course.	(Howard et al., 2019; Hoc loco)
Idea USV.9	Students often use the textbook and other resources more if they are tied specifically to the course at hand, but other factors may affect the extent of use.	(Kock & Pepin, 2018; Hoc loco)
Idea USV.10	Over the course of the first year, students a) start using the teacher less, b) start using internet-based resources more, and c) start using social resources more.	(Stadler et al., 2013)
Idea USV.11	Over the course of the first year, students start seeing a) previous tests as more important, b) peers as more important, c) computer calculation as more important, d) internet-based resources as more important, e) formula books as less important, and f) calculators as less important.	(Stadler et al., 2013)
Idea USV.12	Students change their resource strategies quickly in response to changes within the context and quickly reach quite stable strategies.	(Hoc loco)
Idea USV.13	A typology of resources used by students should group resources used for the same activity, for instance combining fellow students with resources used to communicate with fellow students.	(Anastasikis, 2018)
Idea USV.14	Resource typologies may differ depending on the course. Types may	(Anastasikis, 2018; Hoc loco)

	include peers, teachers, emphasized information resources, external online information resources, students’ own notes; calculation resources and evaluation resources.	
Idea USV.15	Student profiles may differ depending on the course. Profiles may include the peer-learning group, the online-learning group, the blended-learning group, the predominantly textbook-learning group and the selective-learning group.	(Anastasikis, 2018; Hoc loco)
Idea USV.16	The type of goals a student has influences which learning profile they correspond to.	(Anastasikis, 2018)
Related to classes of situations		
Idea COS.1	Students develop documents for wide classes of situations.	(Hoc loco)
Idea COS.2	Students have a “prime document” with resource strategies that they use to learn new mathematical content under circumstances that they consider sufficiently normal.	(Hoc loco)
Idea COS.3	Students use resources differently when preparing for exams. They tend to emulate the exam situation by solving problems from previous exam sets and using only resources that are allowed at exams.	(Hoc loco)
Idea COS.4	Students use resources differently depending on the level of difficulty they experience. When students experience high level of difficulty, they tend to use more non-emphasized resources and work more with fellow students.	(Hoc loco)
Idea COS.5 (and USS.6)	The resources that students use in combination with fellow students differ	(Hoc loco)

	from the resources they use when they work alone. They tend to use text resources more and digital resources less when they work with others.	
Idea COS.6	Several factors may affect students' use of resources, such as the area of mathematics being studied, the degree of familiarity, the time available to the students, the availability of social resources and whether they are working on mandatory assignments.	(Hoc loco)
Related to didactical resource purposes		
Idea DRP.1	Students learn new topics through the phases introduction, practice, evaluation and explanation.	(Hoc loco)
Idea DRP.2	Students tend to use emphasized resources for introduction, and in particular lectures.	(Kock & Pepin, 2018; Hoc loco)
Idea DRP.3	Students tend to use emphasized resources as plan A for practice and use more non-emphasized resources as plan B.	(Hoc loco)
Idea DRP.4	Practice additionally help students assess their understanding.	(Kock & Pepin, 2018; Hoc loco)
Idea DRP.5	The main strategies for evaluation include using social resources, checking answers through the source of the exercises and finding the answer with digital calculation tools.	(Hoc loco)
Idea DRP.6	Students rarely (but sometimes) evaluate their work process. Evaluation of the work process is more likely to occur during the exam period or between courses.	(Hoc loco)

Idea DRP.7	Students appreciate getting additional explanations. Students tend to use video resources to get an additional explanation.	(Kock & Pepin, 2018; Ragual & Ogena, 2012; Hoc loco)
Idea DRP.8	Students appreciate detailed solutions for exercises they have attempted solving.	(Robinson et al., 2015; Hoc loco)
Idea DRP.9	Students use a variety of books, social resources, video resources and search resources for explanation. Among the non-emphasized digital resources, YouTube, Facebook and Google are commonly used.	(Puga & Aguilar, 2014; Hoc loco)
Idea DRP.10	The videos, channels and websites that students find through search resources like Google and YouTube are mostly just utilized. Students rarely start using them frequently.	(Hoc loco)
Idea DRP.11	A table where resources are categorized based on the DRPs they are used for and whether they are used as plan A or plan B can be a useful way to summarize a student's use of resources.	(Hoc loco)
Types of learning		
Idea TOL.1	Compared to secondary school, university mathematics is more difficult and focus more on conceptual knowledge.	(Kock & Pepin, 2018; Furinghetti et al., 2013; Breen et al., 2013; Hoc loco)
Idea TOL.2	Engineering textbooks at the start of university mostly focus on procedural understanding.	(Randahl & Grevholm, 2010)
Idea TOL.3	Students' goals regarding their use of resources in mathematics are mostly tied	(Anastasikis et al., 2017; Anastasikis,

	to assessment. Understanding is also a significant goal.	2018; Howard et al., 2019; Kock & Pepin, 2018; Gueudet & Pepin, 2018; Hoc loco)
Idea TOL.4	First year students' interaction with resources tends to be pragmatic rather than epistemic. Exercises are considered very important by students.	(Gueudet & Pepin, 2016; Kanwal, 2018; Ragual & Ogena, 2012; Hoc loco)
Idea TOL.5	Students appreciate both conceptual and procedural tasks.	(Breen et al., 2013)
Idea TOL.6	Visual tasks and experimental tasks in dynamic geometry environments can facilitate conceptual understanding. Whether students have a conceptual focus may affect the degree of conceptual understanding achieved.	(Hoffkamp, 2011; Swidan & Yerushalmy, 2014; Leung et al., 2013; Hoc loco)
Resource decisions and guidance		
Idea RDG.1	Students' use of resources at the start of University is greatly influenced by their secondary school experiences, but changes as they encounter the university context.	(Stadler et al., 2013; Gueudet & Pepin, 2016; Kock & Pepin, 2018; Gueudet & Pepin, 2018; Hoc loco)
Idea RDG.2	Students tend to have less guidance tied to the use of resources at University compared to secondary school and find it harder to make choices.	(Gueudet & Pepin, 2016; Kock & Pepin, 2018)
Idea RDG.3	The less guidance the lecturer gives, and the more the agency of the student is	(Kock & Pepin, 2018; Hoc loco)

	communicated by the lecturer, the more varied students’ use of resources is.	
Idea RDG.4	When making resource decisions, students may exclusively consider resources they are familiar with through current or previous education, recommendations or non-mathematical uses.	(Hoc loco)
Idea RDG.5	Students often recommend Wolfram Alpha to one another.	(Hoc loco)
Idea RDG.6	Google and YouTube are among the most commonly used resources that students are familiar with from non-mathematical uses.	(Hoc loco)
Idea RDG.7	Students primarily make their resource decisions based on what resources they consider suitable for the task and secondarily based on personal preference.	(Hoc loco)
Idea RDG.8	Students perception of suitable resources are affected by the organization of the course. They often use emphasized resources first and only use non-emphasized resources if they are unable to achieve their goals using the emphasized resources.	(Hoc loco)
Idea RDG.9	Students primary quality criteria include simplicity and the ability to use the resources efficiently. Other criteria include price, breadth of functionality, quality of explanations and ability to control the pace of information.	(Robinson et al., 2015; Hoc loco)

Table 6.3: A list of ideas within the project and existing ideas within the field of research that relate to the project. Includes a total of 55 ideas, ordered into six categories.

6.2 Progression towards the goals of the field of research

In this section, I will relate the updated field of research to the two subgoals of the field of research that I mentioned in the first chapter, namely:

> Gain knowledge on the types of resource strategies one could use to learn mathematics.
>
> Understand the mechanics by which students decide what resource strategies to use.

I will discuss how my results and ideas help progress the field of research towards those goals. This includes consideration of what the new and refined ideas can teach us and how these new perspectives give rise to questions that ought to be investigated further.

My thesis helps further our knowledge on resource strategies that students could use in a variety of ways. The most significant contribution, is the idea that students have strategies for each of the didactical resource purposes (DRPs) introduction, practice, evaluation and explanation. I think this idea deepens our understanding of the students' resource strategies, that it is a good lens by which researchers can study students' use of resources and that it can have practical consequences for how educators design their courses. A course organizer may want to consider whether the resources they emphasize in their courses are sufficient to provide students with the ability to form strategies for each of the four DRPs. Introduction and practice appear to largely be covered by emphasized resources such as textbook, lectures and video lectures and exercises either within the textbook or on digital platforms. The degree to which resource for evaluation are emphasized in the course, for instance, varied quite a bit between the three Universities in the study. At University Alpha, evaluation resources were not emphasized in the course, apart from answers in the back of the book. At University Beta, features of MyMathLabs provided instant feedback on exercises. At University Charlie, plenary sessions and videos thereof gave students detailed solutions for exercises they had worked on. Explanation does not seem to be covered by emphasized resources. To a degree, the same resources used for introduction can be used for explanation, but beyond that, students often use non-emphasized resources such as Google or YouTube. Perhaps, course organizers should emphasize such resources to a larger degree and help students develop good strategies for using such resources when they need explanation.

The DRPs give an overall structure for students' use of resources. Some of the other ideas I introduce also help further our understanding of specific resource strategies. The ideas that students, when they work together, work in groups of three or four; use text resources more and digital resources less than when they work alone and ask each other before they ask the lecturer, can be worth studying further. It may also have some practical consequences for institutions. For instance, when designing spaces for students to work on campus, the preference for groups of three to four may be important to consider.

The mechanics by which students decide on resource strategies are not explored much within the field of research. An existing idea, which my results also support, is that students focus on examination when they decide on their strategies.

My analysis expands on the ideas within the field, by giving an overall structure to students' decision making. Students decide from the pool of resources that are either emphasized in the course or was emphasized in their previous education, as well as recommendations from other students and some resources they are familiar with from non-educational contexts. They primarily make their decisions based on how suitable it is for the task at hand. The degree to which a student perceives a resource as suitable depend greatly on how much it is emphasized in the course. However, when students are unable to achieve their goals using emphasized resources, they have non-emphasized resources as plan B. Given multiple suitable resources, students use personal preference. Students tend to prefer resources that are simple to use and can be used efficiently.

This overview of students' decisions regarding resources to use can be used in further research. For instance, the relation between the degree to which resources are emphasized and the degree to which students see them as suitable can be investigated further. This may in time lead into research on how educators can lead students towards certain resource strategies. While already studied within the field, it may also be worth directing more attention to how perceived difficulty influences students' decisions on how to use resources.

A small result, that may still have large practical consequences, is the indication that students do not like digital resources that they are unfamiliar with. The comments regarding the use of Maxima at University Beta and Maple TA at University Charlie, indicated that these resources were complicated and difficult to use because the students were unfamiliar with them. A practical consequence would be that course organizers should give more consideration into how they present digital resources that are new to the students. The course organizers should not simply try to teach the students mathematics, with the resources as a means to an end. They should try to teach students about the resources themselves, to help students gain the familiarity they need to use the resources efficiently. It is also worth researching whether this difficulty with new resources is exclusive to digital resources or whether it can also be seen in other resources. It may be the a problem for all resources, but to varying extent, with some resources requiring more familiarity than others in order to be used effectively.

For both of the goals for the field of research, the field is young and have barely begun the progression towards satisfactory answers to these questions. The questions themselves are also only stepping stones towards the greater goal that I defined as

> Enable mathematics educators to guide students toward resource strategies that help them successfully learn mathematics.

I hope that my proposed ideas about the structure of both students' use of resources and decisions about resources can be helpful to the field by helping researchers formulate productive research questions and research designs for further research.

6.3 Implications for a documentational approach to learning

In this section, I outline my ideas for what a documentational approach to learning (DAL) would entail, as well as what would need to be determined before it can be used as a theoretical framework. There are many aspects of students' use of resources, so DAL would be open to be used by researchers with a variety of foci. One researcher could have a primary focus on particular resources, but examining them in light of how students incorporate them into their documents. Another researcher could focus on the extent to which institutional influences affect students' development of documents. A third researcher could focus on a single student's documents and how they develop over time, with other aspects as secondary foci. How relevant the terminology within the rest of the section will be to a given researcher will depend on their focus. I divide the section into the subsections general view on learning; overall structure of resource use; views on resources; views on decisions and guidance and questions to be determined.

6.3.1 Views on learning

Personally, I think DAL should be focused on consequences, as is the case in pragmatism. Learning could be defined as any change that increases the flexibility, consistency or efficiency by which students solve mathematical task. For instance, learning can include adopting solution methods to be able to solve types of problems that the students were unable to solve before; it can include students becoming more proficient with solution methods they know; it can include students increasing their understanding of concept and relationships to improve their mathematical reasoning and it can include the students developing skills of mathematical exploration and modelling in order to increase their ability to solve mathematical problems for which they do not know a solution method. However, I think DAL should be open to be used with different paradigms. There should be room for networking with theories such as conceptual vs procedural knowledge (Hiebert & Lefevre, 1986) and epistemic versus pragmatic value of techniques (Artigue, 2002), which are already used by several researchers within the field. Whichever theory the researcher chooses, I do see it as important that the researcher uses a theory on learning mathematics which distinguished between different types of learning.

I think it is particularly important to adopt the attitude that students ought to learn in a way that emphasizes all the three goals of solving mathematical problems more efficiently, consistently and with greater flexibility. It should be acknowledged that a lack of focus on flexibility is a pitfall for many learners.

Within the theory of conceptual and procedural knowledge (Hiebert & Lefevre, 1986), this attitude is represented. The fundamental understanding of concepts and relationship that conceptual knowledge represents and the more specific knowledge on solution methods within procedural knowledge are both considered important and vital to successfully learn mathematics. Researchers tend to find that students focus too much on acquiring procedural knowledge and look for approaches that lead students to develop their conceptual knowledge to a larger degree.

Similarly, studying pragmatic and epistemic techniques linked to use of resources to learn mathematics (Artigue, 2002), one may find that students focus more on the pragmatic value of the activity (Gueudet & Pepin, 2016; Kanwal, 2018). Ideally, one would want students to have a more balanced focus and also consider the activity's potential to help them organize the mathematical ideas involved.

Whichever perspective on learning one chooses to use, gaining familiarity and proficiency with various resources for mathematics can help aid in any of the the types of learning. The overall structure of the resource use is the topic of the next subsection.

6.3.2 Overall structure of resource use

The overall structure of the documentational approach to learning is directly tied to the documentational approach to didactics (Gueudet & Trouche, 2009).

Two students who interact with the same resource, may use the resource in quite different ways. The interaction between a student and a resource is not only dependent on features of the resource and how the designer of the resource intended for people to interact with it. Nor is it entirely dependent on the student's goals and preferred way to work. A student's use of a resource or several resources in combination can be summed up as a joint entity of the set of resources and how they are used, and is the result of interaction between the affordances and constraints of the resource and the goals, preferences and previous experiences of the student. The terminology of the documentational approaches is that a *document* is the joint entity of a set of resources and *schemes of utilization*. Documents are created and developed through the process of *documentational genesis*. It consists of two subprocesses. The process by which a person influences the resource interaction through their goals, preferences and previous experiences is called *instrumentalization*, while the process by which the affordances and constraints of the resource influence the interaction is called *instrumentation*. Student use different resources at different times, so each document is utilized for a *class of situations*. It is also important within documentational approaches to consider the social context in which the interaction with resources takes place, and in particular institutional influences. The set of all documents that a student has, along with what classes of situation they have documents for is called their *document system*, while all the resources that are represented in at least one of the student's documents is their *resource system*. When a student actively work to develop their document system in general, rather than a specific document, it is called *documentation work*. When they work to develop a specific document in response to a specific situation, I will call it *documentational adaption*. I have discussed most of the preceding terms in subsection 2.2.2 (page 14).

Next, I will focus on the terms that need to be understood differently when applied to students rather than teachers.

When defining what to consider a class of situation, one needs to consider level of generality. The more specific one's definition is, the more classes of situations there are, and the greater the similarities between the resource use of the student in question is. DAL should be open to different choices of generality. For a very general interpretation of classes of situations, the following ideas should be included in the approach: Students tend to have a *prime document*, for the class of situations "learning a new mathematical topic within regular circumstances." What a given student considers regular circumstances and what irregular circumstances they have also developed documents for, depend on the student and is of interest to a researcher studying a student's resource use with the documentational approach. Examples include classes of situations such as 'learning a new mathematical topic that I find particularly difficult', 'learning a new topic that closely relates to a familiar topic' and 'learning a new mathematical topic when time is scarce.' Students may also have different documents for different areas of mathematics, or different documents for when certain resources are not available to them. In addition to classes of situations tied to learning new mathematical topics, students have documents tied to preparing for assessment, and examinations in particular.

For such a general interpretation of class of situations, didactical resource purposes (DRPs) would be considered phases within a document. For a less general interpretation, DRPs could be considered classes of situations themselves. The most prominent DRPs are introduction, practice, evaluation and explanation. Given a less general definition ‘being introduced to a new mathematical topic within regular circumstances’, ‘working mathematically in order to learn a new mathematical topic within regular circumstances’ and ‘searching for additional information on a new mathematical topic within regular circumstances’ could be considered classes of situations.

In the introduction phase, students gain a base understanding of the mathematical objects, relationships and solution methods that the topic involves. Within practice, they work mathematically, for instance through applying solution methods to recommended exercises or exploration of mathematical relationships. Through this phase they can test the consistency, efficiency and flexibility by which they solve exercises. The practice phase is closely tied to evaluation, which entails searching for indications that they solve problems correctly or that their work process is beneficial. Explanation occurs at any point after the introduction phase when students actively search for information to improve their understanding of a specific aspect within the topic, whether it is tied to mathematical objects, relationships or solution methods. Students may move freely between the last three DRPs. Within documents tied to preparing for assessment, introduction does not occur, but the rest are still relevant.

In the case of university students, the most direct institutional influences stem from the lecturers and the organization of the courses. They are tangentially influenced by university policy, which effects the lecturers’ work and the organization of the courses. The mandatory assessments within a course greatly affect when each of the students’ documents are used. Especially important institutional factors include which resources are emphasized. In addition to providing resources such as textbooks, lectures, video lectures, information pages and so on, lecturers provide students guidance through recommended exercises, and recommendations for how to work. One difference between the institutional influences affecting teachers and the influences affecting students, is the level of guidance. University administrations give few recommendations for what resources the teacher should use, as they are not expected to know more about effective use of resources to teach than the teacher does. The teacher, however, is expected to know more about effective use of resources to learn than their students and be able to provide helpful guidance to them through recommendations. I will come back to resource decisions and guidance in subsection 6.2.4 (page 269).

The resource system of students at the start of university is greatly influenced by what resources are emphasized in each course and to what extent. In addition to resources emphasized in their current education, their resource system may include resources they have previous experience with. These may be resources that were emphasized in previous education; resources they have been recommended by fellow students and resources they are familiar with from non-mathematical activities. It is rare for students to actively search for new resources to use. The resources they find when they use search resources like the search functionalities of Google and YouTube are often *utilized* rather than incorporated into their resource system. In the terminology of the documentational approach, a *usage* is when a resource is used as part of a document for a class of situations. When a resource is used once and not incorporated into any document, it is called a *utilization* (Gueudet & Trouche, 2009).

For a university student in a mathematics course, documentation work can involve looking for new resources or reflecting on how to change one's schemes of utilization. DAL considers documentational adaption to be distinct from documentational work. While documentation work is pro-active, aiming to further improve one's document system, documentational adaption is reactive, updating documents when faced with a change to the context which result in difficulty using their current documents. For instance, a student may incorporate a new resource because it is heavily emphasized in a new course; they may encounter a new class of situation or a resource that was central to their documents may no longer be available. These situations give extra urgency to updating one's document systems. Students rarely engage in documentation work, but may do so after the conclusion of a course. Documentational adaption, happen more frequently, both at the start of and throughout a course. Students update their documents rather quickly, and primarily incorporate resources from their old resource systems and newly emphasized resources.

6.3.3 Views on resources

The documentational approach to learning recommends a compromise between a wide definition of resources (Adler, 2000) and students' intuitive understanding of the term. If using DAL with a holistic focus, it is recommended to clarify to students that discussion with people and events they attend count as resources, and beyond that use what the students intuitively consider resources. Some perceive the term resources as anything used *in addition to the obvious* (such as lectures or textbook). Researchers should clarify that their working definition goes beyond such a definition to mean 'everything they use to learn mathematics'. If researchers use observation to a larger extent, it is recommended to additionally include mathematical solution methods in the researcher's working definition of resources, but not to include it in communication with participating students.

The rational for defining resources in such an interactive fashion is to get insight into students' consideration of their own resource use, while still ensuring that categories of resources important to the researcher such as social resources are represented. With this definition process, the working definition of resources is unlikely to be as wide as the definition by Adler. For instance, one would not include language as a resource.

Like in the documentational approach to didactics, DAL should define resources to have three component (Gueudet & Trouche, 2009). The *material component* concerns the observable nature of the resources. The resources may be books, computer programs, people, events, etc. When using DAL with a particular focus on the affordances of resources, this component is significant because it relates to the availability of the resources, which greatly influences the likelihood that students would use them. The *mathematical component* of resources concerns what mathematical topics and tasks they have potential to be used for. Along with the mathematical topics of the course, the mathematical component of a resource may help predict the extent to which students will use the resource or shed light on why students are using the resource. Within DAL, the *didactical component* of resources consists of the didactical resource purposes. When researching how significant a resource is or has the potential to be to students, it is worth considering what phase of the learning process the resource may be used for and what purpose it serves within that phase. Is it a resource for introducing students to a topic; a resource for calculation; a resource for organizing information, a resource for checking answers; a resource for actively searching for specific information or a combination of the above.

Depending on one's focus, the importance of the three components may vary. However, they may be more important than expected if students mention categories of resources. Similar to how researchers should be open to include resources that students mention, they should also be open to include resource categories. If the students mention using digital resources more in certain situations, then the material component of resources might be more important to the research than the researcher initially expected.

6.3.4 Views on decisions and guidance

University education is characterized by giving students more freedom than schools do. However, there can be great differences between course organizers. Some may have the view that there are many successful ways to study and that they should give general recommendations rather than to dictate how the students work, enabling the students to choose based on their preferences. The students are expected to be mature learners who can determine whether the lecturers' recommendations work well for them. If they do not, the student should be able to come up with alternative strategies on their own or search for recommendations from other sources. Other course organizers may give students very specific guidelines, outlining a complete set of learning strategies. This might help students who find it hard to work out strategies on their own. However, for students who are proficient at developing their own strategies, and whose strategies differ from the ones outlined by the course organizers, it may seem like a hindrance. In addition to different philosophies on whether to provide a great breadth of recommendations or recommendations with great clarity, the extent to which lecturers aim to make students aware of the degree of agency that they have can vary.

Students tend to use emphasized resources, and the more a resource is emphasized, the more students are likely to use them. In their documents, students tend to incorporate heavily emphasized resources as plan A within a given class of situations, while resources that are emphasized to a lesser extent or not at all are usually part of plan B. If a lecturer provides clear guidance, rather than a variety of recommendations, there is likely to be less variety among the resources that students use for plan A. The more the lecturer communicated students' agency to them, the greater the number of resources used, and variety of resources used, is likely to be.

The documentational approach to learning should not take a stand about whether lecturers and course organizers ought to give clear recommendations or wide recommendation, but recommends communicating students' agency to them. When using DAL, it is important for researchers to investigate the level of guidance provided within the educational context of the participating students, and in particular the extent to which various resources are emphasized.

6.3.5 Questions to be determined

While I think my research establishes a good basis for a documentational approach to learning, I think it is incomplete. One ought to develop theories about several other aspects of students' use of resources in order to improve its potential as a theoretical framework. There is a particular need to research ideas related to the development of students' documents throughout their university education. Projects with longitudinal research designs could greatly help shape a documentational approach to learning. Further research could additionally uncover other issues that ought to be included. In addition, every idea I have presented could benefit from further research, determining whether it can be helpful to other research projects that investigate the use of resources with a student-centered focus and hence how true they are, in the pragmatic sense (James, 1907).

Currently, I primarily have ideas for a descriptive component of DAL. In order to benefit society, the framework could have a normative dimension, helping course organizers structure their course and provide recommendations to guide students towards developing successful documents. In time, and given further research it might be that DAL should adapt a view on whether guidance ought to involve the recommendation of one overarching strategy or a breadth of recommendations. Whether in the case of overarching strategies or resource recommendations, one would want a theoretical framework to contain ideas on how to give students guidance. As I considered in subsection 1.1 (see figure 1.1, page 3), a prerequisite for such a goal would be consideration of what constitutes successful learning; research into what resource strategies lead to successful learning and more research into how course organizers can influence students' resource decisions.

Before the relationship between resource strategies chosen and successful learning can be studied, it might be necessary to further study the potential of identifying student profiles for resource use as Anastasikis did (Anastasikis, 2018). While student profiles can be identified quantitatively, qualitative research could help deepen our understanding of why a student ended up within a given profile. This may lead to a theory of student profiles that can be generalized across multiple contexts providing different resources. Anastasikis' research into possible relationships between student profile and the students' goals is one step towards an understanding of student profiles. Perhaps, in the future, course organizers should consider each of the student profiles and give resource recommendations that provide students of every profile with a chance to learn. Or perhaps students of certain profiles are less successful and course organizers should attempt to guide students away from said profiles.

Lastly, it would be worth looking into the extent to which theories stemming from the documentational approach to didactics can be incorporated into a documentational approach to learning. As an example, documentational trajectory (Rocha & Trouche, 2017) can be used to study the development of teachers' documents with a focus on *events* that lead to changes in their document systems and individual documents. It is worth considering whether documentational trajectory can also be a good model to describe the documentational adaption of students in longitudinal research.

Chapter 7: Conclusions

In this chapter, I summarize my results; discuss the limitations of the research based on quality criteria for conducting mixed methods research and discuss implications for future research.

7.1 Summary of results

Considering what is important to the field of research (see figure 1.1, page 3), my research focused primarily on investigation into students' resource strategies (including what resources they use and how), and into how students make decisions about what resources to use.

I found that resource strategies are highly personalized and that students use a great variety of resources, both when they work alone and when they work with fellow students. Additionally, there is variety to the extent to which students say they work alone and with others and variety to the extent to which they learn from either way of working. A few trends can be identified before considering influencing factors. For instance, students prefer to ask fellow students questions rather than to go to the lecturer, and usually they work in groups of three or four. For identification of further trends, it is worth considering factors such as what resources are emphasized; what purposes students use resources for and what factors lead them to use resources differently from how they normally use them.

Students have a tendency to focus heavily on resources that are emphasized within the course, and the greater the emphasis on a resource is, the more students use it. This leads to great similarities among the resources that students who attend the same course use the most. However, there are exceptions, such as the difference between Benjamin, who focuses primarily on video lectures, and Brage, who primarily focuses on exercises within MyMathLabs. Students also use a variety of non-emphasized resources, including video resources, digital calculation tools, search resources and communication resources. Non-emphasized resources are used less than emphasized resources and the use varies more from student to student.

For most students, their learning process can be described in terms of the phases that I have named them the didactical resource purposes (DRPs). The four phases are introduction, practice, evaluation and explanation. They are characterized by goals of learning the basic theory of the mathematical topic; working on mathematical task for a given topic; evaluating one's work process or one's solution of the tasks and actively searching for information tied to the topic, respectively. With these DRPs I identified several trends of resource use. For instance, students primarily use resources emphasized within the course for introduction. They consider exercises important, particularly with examinations in mind. They spend a lot of time on practice. They mainly check the answers to exercises through the source of the exercises; working with fellow students and solving the exercise with an alternate solution method, such as using digital calculation tools. Many use non-emphasized video resources to get an additional explanation, which is particularly common in courses where there are emphasized video resources. Some use search resources for explanation. The resources they come across through search resources are primarily just utilized.

A variety of factors can lead students to use resources differently from what they usually do. Using the documentational approach, one can call their regular strategies the prime document, and define other documents based on the situations that lead them to use resources differently. One such document is tied to when students experience an increase in difficulty. In particular, students often have heavily emphasized resources as part of a 'plan A' (their prime document), while less emphasized resources, non-emphasized resources and social resources are 'plan B' (and can be interpreted as their difficulty document). Another document is preparation for exams. Students emulate the exam situation by solving problems from previous exam sets and relying mostly on resources that are allowed during the exams. Beyond those two, there is greater variety in the situational factors students feel like they are influenced by. Factors mentioned by students in the project include different areas of mathematics, degree of familiarity, amount of time available, availability of social resources and whether or not one is working on a mandatory assignment.

Related to students' decisions regarding resources, I have found that students almost exclusively consider using resources they are familiar with. Those resources are either emphasized in the students' current or previous education; recommended by fellow students or are familiar to students from non-mathematical uses. They make their decisions largely based on their goals. First, they use the resources that they consider the most suitable, which are usually emphasized resources. If they are unable to achieve their goals using said resources, they go to other resources. Preference also plays a smaller part in students' decision making. Students have a tendency to prefer resources that are efficient. This includes being able to access them quickly; being able to use them quickly and, in the case of calculation, being able to quickly update their solution after spotting an error in one of the steps. They also generally prefer simplicity. Many students in the project disparaged the textbook for being complex and not being in their first language. Less commonly mentioned quality criteria include low price; breadth of functionalities; quality of explanations and the ability to control the pace of the information. Video resources, for instance, give students a lot of control of the pace, as they can skip sections, watch sections multiple times and adjust the playback speed of the videos.

Students' use of resources appeared to develop mostly in response to specific situations or general changes to the context. When such changes occurred, students appeared to update their resource strategies quickly. Afterwards, there appeared to be few instances of students making changes simply based on their own reflection on how effective their current strategies were. However, there was some indication that students reflected on their resource strategies between the examinations in a mathematics course and the start of the next mathematics course they were to attend.

Another aim of my project was to review the literature relevant to the field of research on mathematics students resource use as a whole, in order to identify a) the degree to which my findings were similar to those of other resources; b) how far the field of research has come and c) implications for future research. I will cover the implications for future research in subsection 7.3 (page 283). The following paragraph summarizes literature relating to the results of this thesis:

I summarized ideas within the field in table 2.2 in section 2.5.3 (page 36), giving each idea a number. For many ideas within the field, my research provided evidence to support them. Some of the ideas related to issues that were not among my main foci, while others related to issues that were. Existing ideas within the field of research that my project provided further evidence to support included ideas 1, 4, 5, 6, 8, 9, 11, 18, 24, 25, 31, 32, 33, 35 and 36 (Anastasikis et al., 2017; Anastasikis, 2018; Kanwal, 2018; Howard et al., 2019; Kock & Pepin, 2018; Fredriksen et al., 2017; Borba et al., 2018; Gueudet & Pepin, 2016;

Gueudet & Pepin, 2018; Robinson et al., 2015; Ragual & Ogena, 2012). For some existing ideas, my results support the ideas and go slightly beyond them. This is the case for idea 2 (Kanwal, 2018), in which my research identified additional non-emphasized resources used by students; idea 14 (Kock & Pepin, 2018) for which I add communication of agency to the idea and idea 34 (Robinson et al., 2015) for which I identified several additional quality criteria student had for resources. There are existing ideas within the field of research that my results support, but that I think could be improved by incorporating them into the model of didactical resource purposes. This includes ideas 19, 20, 21, 22, 23 and 37 (Pepin & Kock, 2019; Kock & Pepin, 2018; Puga & Aguilar, 2014; Ragual & Ogena, 2012). For some existing ideas, my results do not provide as much support as one would expect. This includes ideas 3 and 7 (Kock & Pepin, 2018; Anastasikis 2018). There are also ideas that I consider relevant to future research in the field, but that my research does not have the potential to support or contradict given its focus. For instance, these ideas may focus more on differences between secondary and tertiary education or on development over a longer period of time than in my project. This includes ideas 10, 12, 13, 15, 16, 17, 26, 27, 28, 29 and 30 (Anastasikis, 2018; Kock & Pepin, 2018; Gueudet & Pepin, 2016; Gueudet & Pepin, 2018; Stadler et al., 2013; Breen et al., 2013; Furinghetti et al., 2013; Randahl & Grevholm, 2010; Hoffkamp, 2011; Swidan & Yerushalmy, 2014; Leung et al., 2013). Subsection 6.1.7 (page 251) contains a list of ideas based both on my research and on existing ideas within the field.

Lastly, my project aimed to examine the potential of using the structure of the documentational approach to didactics (DAD) (Gueudet & Trouche, 2009) in order to create a documentational approach to learning (DAL), and what implications my research has for DAL. I conclude that the basic structure of the documentational approach is suitable for examining students' use of resources. However, unlike DAD, I argue that it is more useful for DAL to operate with general classes of situations, while also considering didactical resource purposes as phases of the learning porcess within each class of situations. I argue that students' documents include a prime document which details how they use resources when they learn a new topic under what they consider regular circumstances. The classes of situations that give rise to other documents include situations in which students do not learn new topics (for instance preparing for examinations) and situations in which they learn new topics, but certain factors make the circumstances irregular (for instance, the level of difficulty).

I include in my implications for DAL that students' resource systems include resources they are familiar with from emphasis in current or previous education, recommendation from fellow students or experience from non-mathematical uses. When students make changes to their document system, it is usually in response to new contexts or situations, rather than from increased experience within a given context and given situations. I introduce the term 'documentational adaption' as a term for changes to documents that come in response to situational changes and distinguish it from DAD's 'documentation work', which I use for changes to documents that are motivated by improving own resource within a stable context. I argue that students primarily engage in documentational adaption throughout a university course and theorize that documentational work primarily takes place between courses.

Lastly, I argue that the institutional influences are stronger for students than for teachers, as lecturers and course organizers have a strong influence on their students' use of resources. Students rely heavily on emphasized resources. Students appear to primarily use emphasized resources as long as they can achieve their goals with said resources. They go to non-emphasized resources when they experience difficulty. The stronger the guidance from university staff, the more students will use the resources emphasized. The more the university staff communicates agency to their students, the more varied the students' use of resources are. If anything, my research suggests that communication of agency is more important to students' performance than clear guidance. However, my research is not designed to draw conclusions about performance with any certainty. I consider it a hypothesis for future research rather than an implication for a documentational approach to learning.

7.2 Quality and limitations of the research

In this section, I discuss two dimensions of the limitations of my research. I discuss the strength of my results and the degree to which the truth of my ideas should be put into question. I also discuss relevant aspects of students' use of resources that my research has not been equipped to (or intended to) address, which leads into the following section on implications for future research. For the strength of my research, I consider first how my research results can be viewed in light of the perspective on truth within pragmatism (James, 1907) and then how my research process can be viewed in light of the perspective of legitimation within mixed method (Onwuegbuzie & Johnson, 2006).

On pages 31-32 I outlined three criteria for an idea within mathematics education to be true, when adopting the notion of truth from James (1907). The first is consistency of experience. The truth of my ideas will depend on the degree to which other educators and researchers find that they can relate these ideas to their own experiences. Note that with this definition, truth is a continuous scale with more and less true ideas, rather than the binary of true and untrue ideas. The higher the consistency, the truer an idea is. Since my project spans three universities, some consistency of experience can be seen through similarities across contexts. However, all the ideas within my research could benefit from attempts to apply them to further research and look for similarities and dissimilarities of experiences.

Given the consistency criteria, the strength of my results varies. Ideas that are supported by multiple pre-existing research projects are particularly strong. Considering the list of ideas within the field of research in subsection 6.1.7 (page 251), particularly strong results include ideas USV.1-2, that students primarily use emphasized resources, but also use non-emphasized resources and that as a result there is little variety to the resources that students within the same course use the most (Anastasikis et al., 2017; Anastasikis, 2018; Kanwal, 2018); idea TOL.1, that university mathematics is more difficult and more focused on learning than secondary (Kock & Pepin, 2018; Furinghetti et al., 2013; Breen et al., 2013); ideas TOL.3-4, that students' goals are mostly tied to assessment and as a result students focus on efficiency learning (Anastasikis et al., 2017; Anastasikis, 2018; Howard et al., 2019; Kock & Pepin, 2018; Gueudet & Pepin, 2016; Kanwal, 2018); idea TOL.6, that visual tasks can facilitate flexibility learning (Hoffkamp, 2011; Swidan & Yerushalmy, 2014; Leung et al., 2013) and idea RDG.1, that students' use of resources at the start of university are greatly influenced by secondary school experiences (Stadler et al., 2013; Gueudet & Pepin, 2016; Kock & Pepin, 2018). Existing research also give some increased strength to ideas USS.1-3, USV.3, USV.7-9, USV.14-15, DRP.2, DRP.4, DRP.7-8, and RDG.3 (Fredriksen et al., 2017; Anastasikis, 2018; Stadler et al., 2013;

Kanwal, 2018; Puga & Aguilar, 2014; Borba et al., 2018; Howard et al., 2019; Kock & Pepin, 2018).

The second criteria for truth is meaning, stating that a pre-requisite for an idea about mathematics education to be true is for it to have practical consequences. For instance, imagine an educator or researcher who assumed the idea of didactical resource purposes to be true and for whom the idea is relevant and another educator or researcher who assumes it to be false. If their teaching practice or research is the same, then the idea is either meaningless or equivalent to another idea. While my discussion of practical consequences has been limited, I do believe that my general ideas have meaning. Introduction may be equivalent to ‘starting points’ (Kock & Pepin, 2018) and explanation to ‘help-seeking’ (Puga & Aguilar, 2014), but incorporating them into a system gives another dimension to the reflection. I also believe that knowledge of didactical resource purposes would lead educators and researchers to consider students’ need of resources for evaluation to a greater extent than they do currently. Generally, however, I think that discussion of practical consequences can wait until further research have been conducted into the third criteria.

The third criterion is desirable consequences. For an understanding of what is desirable, the practical consequences of assuming an idea to be true need to be positive. One of the limitations of my research is that it is not designed to investigate how various aspects of students’ resource use relate to successful learning.

With regards to legitimation based on the perspective of mixed methods (Onwuegbuzie and Johnson, 2006), the authors discuss legitimation for quantitative and qualitative research as well as for mixing the research approaches. I will focus primarily on legitimation of qualitative research, since my research is primarily qualitative. Onwuegbuzie and Johnson refer to what was at the time an upcoming article (Onwuegbuzie & Leech, 2007) discussing a total of 29 threats to the credibility of qualitative research. I will not discuss all 29, but instead pick some that I consider particularly important to address. These are issues that challenge the credibility of at least some of my ideas. I will start with threats to internal consistency:

Voluptuous legitimation (Lather, 1993; Onwuegbuzie & Leech, 2007) involves the researcher's interpretation going beyond what there is basis for in the data. The idea that communication of agency lead to performance would run foul of this criteria, which is why I am careful not to give too much credence to it. Said idea also qualifies as a *causal error* (Onwuegbuzie & Leech, 2007). However, I would argue that it is valuable as a hypothesis, in order to raise ideas for further research. *Structural corroboration* (Eisner, 1991; Onwuegbuzie & Leech, 2007) as a quality criteria means that the use of multiple types of data to support and contradict an idea increases its credibility. In my research, themes that are supported by app data and schematic representation of resource systems are stronger than the ones identified merely based on the interviews. *Observational bias* (Onwuegbuzie, 2003; Onwuegbuzie & Leech, 2007) concern insufficiencies in the sampled data. In my project it is a weakness that students filled information into the Studert app to a varying degree, ranging from filling in every study session to none at all.

Researcher bias and *confirmation bias* (Onwuegbuzie, 2003; Onwuegbuzie & Leech, 2007) are particularly important threats to internal and external credibility. A researcher can actively (through leading questions) or passively (through subtle, non-intended signaling) influence the data that participants provide them, leading to a priori assumptions being reinforced. Or they may wrongfully interpret results in a way that reinforces their assumptions. In my research I have made an effort to include open questions and use neutral language to minimize researcher bias and be aware of my assumptions to minimize confirmation bias. Because I did prompt students to talk about specific topics, there is some researcher bias. Still, I found that even in the face of questions with biases, students might answer (and I might interpret their answers) in ways that contradicted the a priori assumptions. My questions may have been biased in favor of changes to students' use of resources, but students reported that the changes were few. My questions were biased in favor of resource use varying depending on areas of mathematics, but few students said that it was the case. My questions were biased in favor of preference being important to students' decision process, but students clarified that it was a secondary concern. I think these results that contradict my assumptions are particularly credible given the criterion of researcher bias. So are results that I had no prior assumptions for. The theme category didactical resource purposes, for instance, was not part of my research focus going in, but I identified it based on a great number of statements by the students.

Reactivity (Onwuegbuzie, 2003; Onwuegbuzie & Leech, 2007) involves the possibility that participants act differently because they are part of a study. While it is particularly important for intervention studies to consider this pitfall, it can occur in other studies. I do suspect that Amalie and Anna may have shared less than they would have if they talked to a fellow student, as they seemed the least comfortable in the interview situation. I do not, however, see any reason to doubt the data I did receive, with the exception of strategies that Adrian mentioned, but that were contradicted by app data (see section 4.2.1, page 98).

Many of the threats to external validity listed by Onwuegbuzie and Leech (2007) relate to similar issues as consistency of experience, for instance *action validity* (Kvale, 1995; Onwuegbuzie & Leech, 2007) and *generalizability* (Daniel, 2003; Connolly, 1998; Onwuegbuzie & Leech, 2007). Other threats include *interpretive validity* (Maxwell, 1992; Onwuegbuzie & Leech, 2007), which involves the degree to which the researcher's interpretations represents the meanings within the group that is studied. Here, it is difficult to ascertain the validity for results where I theorize beyond students' statements. Results that relate directly to their statements, such as exercises being considered important, score highly by this criterion.

Onwuegbuzie and Johnson (2006) operate with nine quality criteria unique to mixed methods. *Sample integration* involves how well the qualitative and quantitative sampling designs work to serve the purpose of the mixing. Considering mixed method is used for triangulation, I think my choice of an identical sampling design was justified. *Inside-outside* involves the extent to which the researcher is clear about what part of their writing describes their view as an outsider and what parts describe the insider's view of participants. I will leave it to the reader to judge whether my research fulfills this criterion. *Weakness minimization* involves the degree to which the qualitative research in the project compensates for the weaknesses of quantitative research and vice versa. I think my study does this to some extent. I have brought some quantitative aspects into analysis by counting the number of statements from each student relating to a theme/result and distinguishing between results (based on statements from less than half the participants) and themes (based on statements from more than half the participants). This has eliminated some researcher bias (which is one of the weaknesses of qualitative research), by forcing me to realize that some ideas that I remembered well because they fascinated me, were not seen across the data, and thus were merely results.

Sequential legitimation is not relevant to my concurrent mixed methods design. *Conversion* involves the extent to which using both quantitative and qualitative methods yield high-quality meta-inferences. I will concede that the app data did not provide as much extra benefit to the study as intended. However, it did cast a different light on Adrian's use of resources by showing how little he used some of the resources he had mentioned. *Paradigmatic mixing* involves the logical connections between the researcher's ontological and epistemological assumptions and the use of mixed methods. I personally consider my research design to be logically tied to my aims, but I will leave the judgement to the reader.

The last three involve the relationship between qualitative and quantitative research. *Commensurability* involves the degree to which the design, analysis and description within the project show proper respect for both traditions. *Multiple validities* concerns the agree to which the legitimation process of both types of methods concern all three types of legitimation (qualitative, quantitative and mixed methods legitimation). *Political* involves the extent to which the inferences in the project stem from both qualitative and quantitative components. In general, for a mixed methods study, my project is a bit unbalanced and favor qualitative components in the inferences, which is why I chose to also primarily focus on qualitative legitimation. However, I think both traditions are properly represented in the way I discuss knowledge and reality.

Moving on to aspects of resource use that my research is not equipped to address, my research does not go far towards investigating causality between aspects of resource use and performance. It does not investigate affective issues or go in depth on discursive issues. It is lacking in its ability to compare resource use at university to resource use in previous education and it only looks at the evolution of resource use over one semester.

7.3 Implications for future research

The field of research could benefit from further research into the existing ideas within the field (see subsection 6.1.7, page 251), as well as aspects of students' use of resources for which there is no research. All the ideas within this project could benefit from more research to check for consistency of experience and possibly expanding on the ideas and gaining deeper insights or additional perspectives. In particular, more longitudinal research, research with a greater focus on performance, and research looking at affective issues and discourse could provide new insights into the field of research.

The idea of individually minded and socially minded students could be investigated further in order to refine the idea, investigate the usefulness of the idea and answering questions such as A) Is there a correlation between being an individually minded learner and being an introvert? B) Are there differences in university performance between people who are individually minded, socially minded or both? C) Is there a difference in career performance? D) If there are such differences, is it because one type of learner is an inherently better learner or because the universities and the job market are inherently biased towards one type of learner? E) If the former, is it possible for students to change the kind of learner they are? F) If the latter, can the university and the job market change to combat such biases?

The development of student's use of resources and the view on the importance of resources (Stadler et al., 2013) could be developed further. Is the tendency towards using more social resources and viewing them as more important a general trend? Does the trend continue beyond the first year at university? It would also be useful to further investigate my ideas that students use different resources when they work with others and that they ask fellow students before the lecturer. It would be useful to see if other researchers have similar experiences, and to study the phenomena in more detail in order to better understand why one sees such results.

In general, research that goes beyond describing students' use of resources in order to look at correlation (and possibly causality) with performance would be important to the field. Is there a positive correlation between using resources for additional explanations and performance? Is it better to attend lectures rather than to watch videos of lectures? Do visual task help students learn? Is it better to use a greater variety of resources? Is students' use of resources for evaluation good for their performance? Should students evaluate their work process more? Can student profiles be developed and used to predict performance? Can students be guided towards successful student profiles, and if so, how? For all the questions, both university performance and performance after university would be worth looking into.

Related to a didactical approach to learning, further research could evaluate whether the structure is useful. Should the interpretation of classes of situations be as wide as in DAL? Do students have prime documents? Are the most common other documents ones for increase in experienced difficulty and exam preparation? What other documents do students have? Is the idea of didactical resource purposes (DRPs) easy to apply to research at other universities? Could documentational trajectory be a good model to investigate the evolution of students' documents? Does a table with resources used for each DRP and as plan A and plan B provide a useful summary of a students' use of resources?

There may be a great deal more for researchers to discover about students' resource decisions and how they relate to the guidance of lecturers and course organizers. Is my interpretation that students only use resources they are familiar with consistent with results in future research? Do other research show efficiency and simplicity to be the most important quality criteria to predict students' preference? Are the resources that students prefer the same as the ones that better facilitate their learning? How can one develop resources that both facilitate students' learning and are liked by the students? How important is it that educators give clear guidance? How important is it to communicate a sense of agency to the students? What are the affective issues tied to resource decisions and guidance? Are learner identities relevant to students' resource decisions?

In general, students' resource use as a whole within mathematics courses in STEM programs is a rather new field of research, and a great deal of research is needed to refine and solidify current ideas and provide new ones in order to further the field.

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Appendixes

Appendix A: Interview agenda for the first round of interviews

Can you say a bit about how you use resources in mathematics courses?	**p**☐
Which resources do you use?	**s**☐ **p**☐
How do you use them?	**s**☐ **p**☐
Can you give an example?	**s**☐ **p**☐
Which resources are used in which situations?	**s**☐ **p**☐
How do you decide which resources to use in a given situation?	**s**☐ **p**☐
How do you categorize situations?	**s**☐ **p**☐
Can you give an example?	**s**☐ **p**☐
To what extent to you use resources emphasized by the university and other resources?	**s**☐ **p**☐
How have you come across the other resources?	**s**☐ **p**☐
Are there any resources you have made your own?	**s**☐ **p**☐
Do you use any resources you think are particularly good or bad?	**s**☐ **p**☐
Is there a connection between how much you like a resource and how much you use it?	**s**☐ **p**☐
Does the use of resources vary from topic to topic?	**s**☐ **p**☐
Do you often ask questions to the lecturer or other staff?	**s**☐ **p**☐
Do you often study with other students?	**s**☐ **p**☐
How often?	**s**☐ **p**☐
With how many?	**s**☐ **p**☐
Is there a difference between how you use resources when you work alone and with others?	**s**☐ **p**☐

Table A.1: The interview agenda I created for the first round of interviews.

Appendix B: Transcription scheme

Transcription scheme

In the original transcriptions, most of the text is verbatim. However, I transcribe in a way that keeps track of certain peculiarities in someone's speech, for instance related to pausing in a sentence or "restarting" a line of thought.

- **(Number)** Implies a brief pause in the student's speech and the length of said pause in seconds. For instance, the section "formed by (1.0) these three points" from the example below signify a one second break between the words by and these. Only pauses that are long enough to imply that the student stops to consider their words are marked. For instance, a one second pause after the end of a sentence is considered normal, while a half second pause in the middle of a clause is not, and implies a break to think.
- **[Name/word]** Either a name or a word has been replaced with a pseudonym, or the student's physical movements while they are talking is described. "[Inaudible]" is used when I am unable to make out the student's words from the recording.
- **Word…** Implies that the student extended the last word. Might indicate that they consider their next words. For instance, the section "and then check… you see that" signifies that the student extended the Norwegian word for check long enough to suggest that he was thinking about how to continue.
- **Word** – **word** The student's tone of voice suggest that in order to rephrase the sentence they had started on, they start the sentence or part of the sentence over again. Students may also restart their current line of thought following an extended word or a break, signified by "…" or a number in parentheses. Hyphen is for when there is a new line of thought with no break in between.
- **Wo…- word** The student stops in the middle of a word, and then either starts over at the beginning of the word or says a different word when they resume.
- **Wo… (Number) -rd** The student pauses in the middle of a word, but eventually resumes with the word.
- **'Word(s)'** The student's tone of voice implies that they are relaying what they or a hypothetical person (or textbook) may say or think in a given situation. For instance, the segment "'check if all points lie at (1.0) er, this or that geometrical object, formed by (1.0) these three points, of the four points'" is Adrian phrasing a hypothetical mathematics problem, not him instructing the interviewer to engage in a mathematical task. The segment "'oh, no, wait, that point actually does not lie (0.5) on… in the plane'" is

Adrian relaying what he might think after checking GeoGebra when working on the hypothetical problem.

Translated example

A1 as soon as you get to something like having (1.5) all these points, ‘check that it lies on’ – or that – ‘check if all points lie at (1.0) er, this or that geometrical object, formed by (1.0) these three points, of the four points’. Then it can be very nice to just *smeise* it into GeoGebra once you are done, and then check… you see that (0.5) ‘oh, no, wait, that point actually does not lie (0.5) on… in the plane’ and so on. (Adrian 1,9)

Appendix C: Scheme for constructing schematic representations of resource systems based on mind maps

Item categories

When the students construct their mind maps, they do not indicate what each box (here called an item) represents in terms of whether it is a headline, a resource a category of resources, etc. However, I decided to make the differences in the structures of the mind maps visually apparent by categorizing the items. How I categorize an item affects the shape and color of the box when I construct the SRRS. The font size and the thickness of the border is also affected. Some items are considered double coded, for instance if the students write a sentence that includes both a resource and a purpose. The categories are:

- Headline
- Resource category
- Situation
- Resource
- Purpose
- Feature or specifics

The distinction between resource category and resource can be open to interpretation. As an example, the internet could be considered a resource, but if the internet connects to several internet-based resources, I would argue that it is used as a resource category in the mind map at hand. When deciding on whether to consider something a resource or resource category, my criteria was that if the item connected to multiple resources and the item could be considered to be what those resources had in common, then the item is a resource category.

The distinction between a situation and a purpose can also be open to interpretation. For instance, is repetition a purpose you use resources for, or a stage in the learning process that can be considered a situation. I coded it as a situation whenever I considered both interpretations to be valid. I labelled one box as both a situation and a purpose. When the item “internet” connected to “searching when having problems”, I interpreted it as meaning ‘when I am in a situation where I am having problems, I use the resource internet for the purpose of searching for assistance’.

The distinction between a purpose and a feature is that I consider it a feature if the sentence “I use resource X because it is Y” makes more sense than the sentence “I use resource X in order to Y”.

How the item categories are represented

All items use the font Calibri.

Item category	Color	Shape	Border	Font
Headline	Red	Round	5px	22pt, bold
Resource category	Blue	Rectangular	5px	20pt, bold
Situation	Green	Round	3px	18pt
Resource	Light blue	Rectangular	3px	18pt
Purpose	Purple	Rectangular	3px	18pt
Feature/specifics	Gray	Rectangular	3px	18pt

Table C.1: The formatting of the various items in schematic representations of resource systems in this thesis. Note that px means pixels and pt means point.

If an item is double-coded and one of the categories is situation, the half that corresponds to the situation is a rounded rectangle.

Connection between items

The students used four different ways to connect items. The most common was with simple lines between boxes, which I replicated in the SRRS. A few students wrote one item as a box and wrote items connected to it as points below the box. To represent this, I attached the connected items as boxes below the first item and made the upper item wider than the other boxes. See the example with Adrian’s mind map below. Casper used two types of connections that no other students used (see example below). He connected boxes with arrows to indicate the order in which he used the resources and used a modified curly bracket to connect “pencil & paper” to multiple items. I replicated both types of connections.

Examples

Between them, the following two SRRSs contain every category of items and every way to connect items.

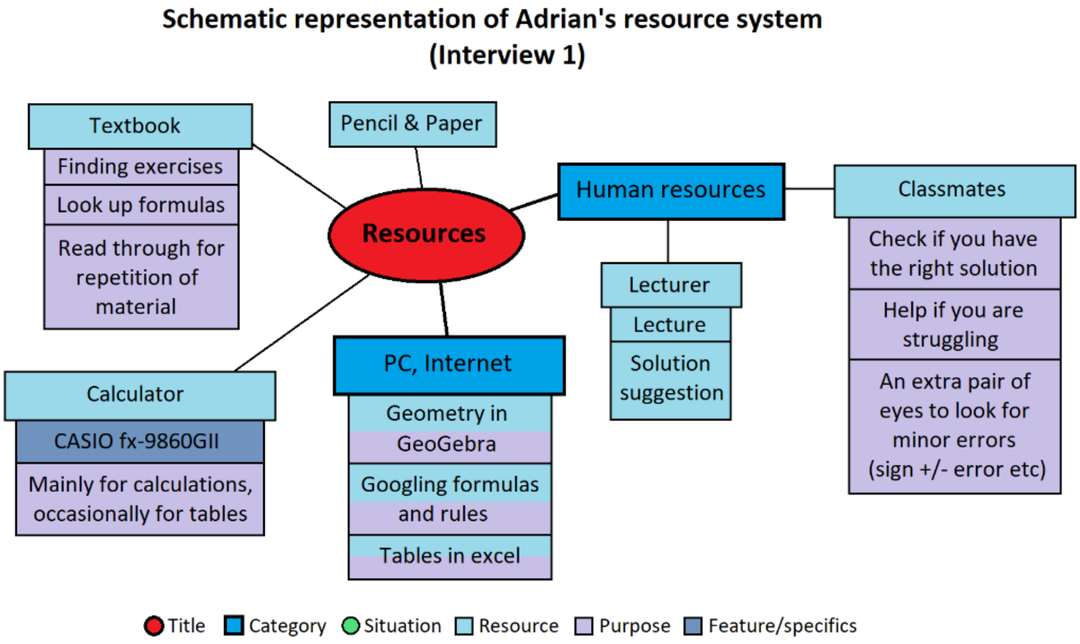

Figure C.1: The SRRS based on Adrian's mind map from the first interview. Exemplifies the formatting of the item types headlines, resource categories, resources, purposes and features/specifics, as well as double-coded items.

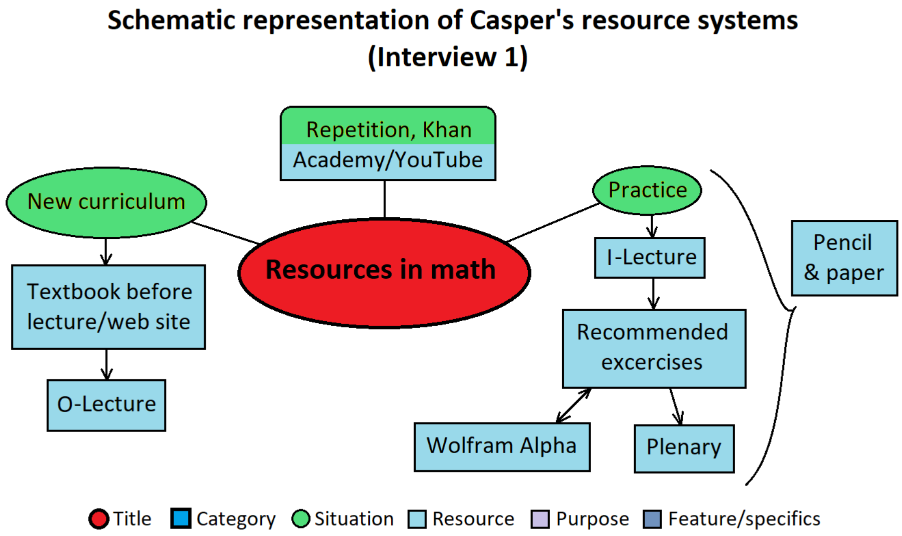

Figure C.2: The SRRS based on Casper's mind map from the first interview. Exemplifies the formatting of the item types headlines, situations and resources as well as double-coded items.

Appendix D: Translation scheme

The interviews were conducted using rather informal Norwegian, and most of the students responded as informally. I tried to translate the interviews in such a way that they came across as informal in English as well and tried to find words that carried the same meaning. Preferably, I would have liked to write the sentence I think the same student would have used, were they a native English speaker. However, in order for the transcription of pauses to make sense, I often had to stay closer to the original Norwegian sentence structure than one normally would, when talking or writing in English. Sometimes, they also apply Norwegian grammar to an English word.

When I toggle italics on or off for a particular word, it is because I use the student's exact words. For instance, the student may have used an English word in the middle of a sentence, or there may be a Norwegian word that I do not think translates well. If the latter, a translation note can be found along with the quote in appendix I.

Here are some peculiarities of speech that were hard to translate and how I dealt with them:

- The word *jo*. *Jo* caries the same meaning as adding 'right' at the end of a statement in English. The speaker communicates that they assume that they are saying something that may be obvious to the listener. A major difference is that in Norwegian sentences, *jo* is often placed after the verb. If one used it in English a sentence might be "I use *jo* mostly the resources emphasized in the course." If possible, I try to translate *jo* into ending the sentence with right. However, in cases when I see the sentence structure as too important, I instead place 'of course' at the start or in the middle of the sentence.
- In Norwegian, a sentence on the form "regarding X, you said Y" would often place the word *så* (meaning then) right after the comma. It often happen that the interviewee or I would pause after *så*. In these cases I would write the pause after 'you' in the translation. So, a statement originally on the form "angående X, så (1.0) sa du Y" would translate to "regarding X, you (1.0) said Y".
- Some people, when speaking informal Norwegian, will ignore the pronoun 'I' when it is clear that they are talking about themselves. While to my knowledge, this is not usual in English, I will leave out the pronoun in translation when the interviewee have done so in the sentence.

- Some students also used pronouns translating to ‘one’ even when they were clearly discussing their own strategies and it was debatable whether many other students would do the same. I decided to reflect this in the translation, rather than correct what I personally considered a rather strange way to phrase the statements.
- When used at the start of the sentence, the Norwegian words for yes and no can take different meanings. With the right tone of voice, they can have the same meaning as starting a sentence with “well”. Yes can also mean “I see” or “right” in response to a previous statement by someone else. I have decided to translate them to well, or I see, as I think it would be confusing to the reader if I translated them to yes.
- Even though the communication was rather informal, I decided to write “have not” and “do not” rather than “haven’t” or “don’t” in the translation.
- Can/cannot. In Norwegian, the word *kan* is often used to mean “is able to do”. I consider sentence structure when deciding whether to translate *kan* into ‘can’ or ‘is able to do’ and whether to translate *kan ikke* into ‘cannot’ or ‘is not able to do’.

Appendix E: Scheme for referring to excerpts

The excerpts included in the thesis have been transcribed and translated as described in appendixes B and D, respectively. In the thesis, I refer to excerpts in the short form. It includes the code of the student; the statement (indented); and the quote location (in parentheses). The font is Calibri, size 10. For the purpose of the quote location, each interview has been split into sections. For instance, the first interview with Adrian consists of Adrian 1,1; Adrian 1,2; Adrian 1,3 and so on, while the second interview starts with Adrian 2,1. Each section consist of a question from me and the entirety of the students' answer. If the student asks for clarification on a question and I give them one, it is included in the same section as the question itself.

For each excerpt, the long form of the excerpt is included in appendix I. It includes the quote location and context, and whether I think my question prompted the answer. In part, the description of context can help the reader decide if they agree with the degree of prompting in the quote categorization. For context, I describe the question of the section that the excerpt is from, and possibly what proceeds or follows the excerpt. I may also give some further context when I think it is needed to understand the excerpt. For instance, some terms may require an explanation on how they are commonly used in the Norwegian language. At other times, the student may refer back to something they discussed earlier in the interview.

On the question of whether I think I prompted the answer, I use three categories, written below "quote categorization":

- Prompted. The student answer simply serves to confirm or deny an assertion in my question, without providing additional details or examples. I also use this category for a question where I ask for and they answer with a numeric interval.
- Semi-prompted. The statement mainly comes from the student, but my question is a bit narrow, in that it prompts them to talk about a specific resource or a rather specific aspect of their use of resources.
- Unprompted. The statement comes from the student, to an open-ended question, or goes so far beyond the scope of the question that I am confident that I influenced the answer to a very small degree.

Example (short form)

A1 as soon as you get to something like having (1.5) all these points, ‘check that it lies on’ – or that – ‘check if all points lie at (1.0) er, this or that geometrical object, formed by (1.0) these three points, of the four points’. Then it can be very nice to just *smeise* it into GeoGebra once you are done, and then check… you see that (0.5) ‘oh, no, wait, that point actually does not lie (0.5) on… in the plane’ and so on. (Adrian 1,9)

Example (long form)

<table>
<tr><td>Quote location:
Adrian 1,9</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
as soon as you get to something like having (1.5) all these points, ‘check that it lies on’ – or that – ‘check if all points lie at (1.0) er, this or that geometrical object, formed by (1.0) these three points, of the four points’. Then it can be very nice to just smeise it into GeoGebra once you are done, and then check… you see that (0.5) ‘oh, no, wait, that point actually does not lie (0.5) on… in the plane’ and so on.

Original:
med en gang det kommer til ting som at du har (1.5) alle disse punktene, sjekk at den ikke ligger på – eller at – sjekk om alle punktene ligger i (1.0) Eh, dette og dette geometriske objektet, dannet av (1.0) disse tre punktene her, av de fire punktene. Da kan det jo være veldig greit å bare smeise det inn i geogebra når man er ferdig, og så sjekk… – ser man at (0.5) oi, nei vent, det punktet det lå faktisk ikke (0.5) på… i planet og så videre.</td></tr>
<tr><td colspan="2">Context:
Asked if his use of resources varies from topic to topic or between mathematics courses. Answers that for topics that are geometrical in nature he uses GeoGebra more and gives an example. In Norwegian, Smeise means inserting something into something else in a careless manner, but is often used a humorous way to say putting something into something else.</td></tr>
</table>

Appendix F: Interview with Andersen

This appendix contains my translation as well as the original transcription of the interview I conducted with Andersen in December, 2017:

Translation:

[Prior to recording, I explained the three sub-questions included in the question]

I: Can you say a bit about how the course is organized?

Andersen: Well. I guess it is [laughs] quite traditional (0.5) in my eyes, that we… It is… (0.5) we have three (1.5) Two-hour lectures a week. Er, and… (1.5) there it is completely one way… communication. It is me lecturing. And since it is… (1.5) Since it is the first… (1.5) their first year, I (0.5) spend relatively much time doing exercises for them, many examples, with – it is more – they are… (1.0) Well, they get a lot more… (0.5) Er, we progress slower than in later… later courses and such. So then, as I said, I lecture three times a week. Relatively much focus on… Exer… – on examples. And then there is… (1.0) er, the lectures are streamed. And… so it is out there, it (1.5) leads to (2.0) maybe there is (0.5) lower attendance on lectures then it would otherwise have been. Yeah, I guess it is pretty obvious that it is. And then, in addition I put out – after each lecture I publish the lecture notes, I write them – I write on… (1.0) I have brought a bunch of A3-sheets and then I write – and then there is a… (1.5) what is it called? Document camera, right, which shows – I sit with my front to the students and… (1.0) and show what I am writing on… on a sort of screen, or canvas, I guess. Yeah, and then we have (1.0) three – throughout a semester there are three assignments. And then two must be approved for you to get to take the exam. Yeah, and er, otherwise it – of the – it has been… (1.0) It is like… (3.5) Yeah, that they have some – we call it homework help, right, when there is an older student, a good one, that – who helps – [they] can come (1.0) get some help to solve exercises and such a few afternoons a week. Yeah. Yes, I guess that…

I: And… when it comes to… what you *legger opp** for them to use, I assume that you have… Er, a textbook, for example. Er (0.5) Are there other things (1.5) you *legger opp* for them to use?

*Translation note: The Norwegian term *å legge opp* is derived from the volleyball term for delivering a setter (a pass leading into a smash). It refers to doing an action X that you expect for someone else to respond to with a specific action Y. The expression is used when the other person have a freedom to choose, but it will be obvious to them that you performed action X with the assumption that they would then perform action Y.

Andersen: No. It is not any more than… than textbook, I collect… (0.5) It (1.0) I suspect that there are pretty few who read a good deal in the textbook. It is in English, (1.0) and by many – it is used (1.0) by many… (1.5) by many educational institutions in Norway. And… I guess it is (2.0) It is considered by most as a good math book, but it is my impression that the students are not as fond of it as. But at least that is where we get the exercises from, so… but I think there are many who… who might settle for my lecture notes, and then look at them and not… read much (0.5) of the book.

[I ask if there is anything he would like to add about the course. There is not.]

[I finish the interview]

Original:

[Før intervjuet forklarer jeg litt hva jeg er interessert i]

I: Kan [du] fortelle litt om hvordan kurset er lagt opp?

Andersen: Tja. Det er nok [ler litt] helt tradisjonelt sett med (0.5) mine øyne, at vi… Det er jo… (0.5) Vi har altså tre (1.5) dobbelttimer i uka. Eh, og… (1.5) der er det jo helt enveis… -kommunikasjon. Det er jeg som foreleser. Og siden det er… (1.5) Siden det er første… (1.5) Det første året deres så (0.5) bruker jeg vel forholdsvis mye tid på å regne oppgaver for dem, mye eksempler, med – blir mer – de er… (1.0) Ja, de får mye mer… (0.5) Eh, vi går saktere frem enn i senere… senere kurs og sånn. Så da foreleser jeg som sagt tre ganger i uka. Forholdsvis mye vekt på… Opg… – på eksempler da. Og så blir jo da… (1.0) eh, forelesningene streama. Og… så det ligger ute det (1.5) fører jo til at (2.0) kanskje er (0.5) dårligere oppmøte på forelesningene enn det ellers hadde vært. Ja, det er vel ganske åpenbart at det er. Også i tillegg så legger jeg ut – etter hver forelesning så legger jeg ut forelesningsnotatene, jeg skriver jo – jeg skriver jo på… (1.0) jeg har jo med meg en bunke med A3-ark også skriver jeg – også er det sånn der… (1.5) hva heter det for noe? Dokumentkamera, ikke sant, som viser det – jeg sitter med fronten mot studentene og… (1.0) og viser det jeg skriver på… på en sånn på en skjerm, eller lerret, da. Ja, og så har vi (1.0) tre – i løpet av semesteret så er det tre innleveringer. Og da må to være godkjent for at du skal få gå opp til eksamen. Ja, og eh, ellers så – av sånn – så har det jo vært… (1.0) så er det jo sånn… (3.5) Ja, at de har litt – det vi kaller leksehjelp da, at det er en litt eldre student, en litt flink en, som – som hjelper – kan komme (1.0) få litt hjelp til å løse oppgaver og sånn noen ettermiddager i uka. Ja. Ja, det er vel…

I: Og… litt sånn i forhold til… hva dere legger opp til at de bruker, jeg regner med at de har… Eh, lærebok for eksempel. Eh (0.5) Er det noe andre ting (1.5) dere legger opp til at de bruker.

Andersen: Nei. Det er i grunnen ikke noe mer enn… enn lærebok, jeg henter jo… (0.5) Det (1.0) Jeg mistenker at det er ganske få som leser noe større i læreboka. Den er på engelsk, (1.0) og blir jo av – den brukes jo (1.0) av mange… (1.5) på mange læresteder i Norge. Og… Den er vel (2.0) Det blir vel av de fleste betraktet som en god mattebok, men jeg har inntrykk av at kanskje ikke studentene er like glad i den som forelesere. Men det er i hvert fall der vi henter oppgavene fra, da, så… men jeg tror det er en god del som… som kanskje nøyer seg med mine forelesningsnotater, og så ser på dem og ikke… ikke leser så mye (0.5) i boka.

[Jeg avslutter intervjuet].

Appendix G: Interview with Bjørnsen

Following is my translation as well as the original transcription of the interview I conducted with Bjørnsen in December 2017

Translation:

[Prior to recording, I explained the three sub-questions included in the question]

Bjørnsen: What I do is in some ways… (1.0) ehm… (1.0) they have, I guess, a lot of freedom, in that the plan lies – they can actually start in Canvas and then start week one and work their way down the points. And bla, bla, bla, it (1.0) I mean… (1.0) And there, there are links to videos, there are links to material they will go through, er (1.0) and… links to the tests they should do, er, the homework they should do, if they want to do it online. They can also do it in the textbook, because the textbook forms the foundation. Er, so they do not have to do things online. Er… (1.0) so that is the basis, and th… – but then I also… (1.0) Ehm (0.5) I have (0.5) then, in both courses* (1.5) I have run two hour lectures a week, that I did not do before. Er (0.5) and it (1.0) and then I do not quite lecture like I would, er… (1.0) traditionally, before. Because what I have now done, is to take the main points for what we have done, and I go through and maybe do an examples, and then I say, ‘this is what is important, this is what you need to remember’. And then ha… – (1.0) if you take (1.0) [MA-X], then they have group wo… –group tasks that they are to work on, er… (1.0) that are relevant for the paper exam, because they have not had paper exam before (0.5) [the ones] who are on their second year now. So they will have it tomorrow, and it will be exciting* to see how they do. Er (1.0) and that I will do in [MA-Y] after Christmas. And now before Christmas, it was [Berntsen] who had the lectures, so I let her… ‘then you do what you think is sensible for the lectures’. But I count on her to… (2.0) er, or (0.5) that she also uses the main points and the essence of what they are to (0.5) go through each week. Ehm (2.0) and [coughs] and then there is – they get – every week they get (1.0) ehm… exercises from the textbook. Or they can sign in and do it in MyLabs, online. That is the choice they make. And then they have assignments that count on the e… – the grade. Three per semester.

*Translation note: The Norwegian word *spennende* can be used to mean exciting, but also, as here, as relating to suspense, rather than excitement.

**Context note: The course “Mathematics X” spans one semester and includes both students in the first year and the second year of the engineering program. The course “Mathematics Y” spans two semester and is only for first year students. The participants “Benjamin” and “Brage” are second year students and only takes Mathematics Y during the semester studied.

[We have a brief discussion about why he and the students sometimes say MyLabs and sometimes MyMathLabs. The bottom line is that they can be used interchangeably]

I: So, how is an ordinary week (1.5) would you say?

Bjørnsen: Ehm… (1.0) I th… – yes, an ordinary week is, I w… – (2.0) they work rather differently, some of those students. Er… (1.0) It is – I know… (0.5) I have talked with some (1.0) who say that many of the ones on electro, choose to sit in the lab, where – it sort of is their home, even though it is (1.0) two rooms to the side, they sit there rather than sitting where I am when they do exercises, for instance. So I guess I have (1.0) in average in [MA… (1.0) X] (1.5) it is around ten out of… (1.0) Thirty-two to -three who – who comes to (1.0) the locale where I sit. Er, but I know that the rest, they sit in (2.0) they sit in the other locale and they do not always work om math when they (1.5) have math lessons, but like (1.0) ehm… (0.5) electro has a lot of lab work, and they have several courses where they have projects – so it – it might be a bit, er… Like… (2.0) They s… – I notice that when they have projects, they sort of fall out from math and work on (0.5) electro courses and then I notice when they have… (0.5) before the tests and such it is… (1.5) can be a lot of *trykk**, right. And then it is (1.0) as it always is in – no matter the course I have, in [MA-Y] first – that is [Math Y], I… (1.0) Ehm… (2.0) I have – [Berntsen] who have had the lectures, and then I have had [Bøe] to take two hours and then I have had two hours (0.5) that are purely practice, and they var… (1.0) Er, the last two hours on Thursdays, not many people come. Then it is the usual (0.5) 4-5 people who (2.0) who are there, but again, they say that a lot are sitting at the electro lab. (3.5) Yeah. And then (1.5) er… s… – I have noticed some difference depending on the topics. In [MA-Y] there is a lot of repetition, and then (1.0) er, they might think they got it. And then you get to complex numbers, which they have not had, and then there are more who show up, and so on.

*Translation note: While *trykk* can mean pressure in both the scientific sense and the sense of social expectations, it can also be used to mean intensity, in the sense of a high workload in relation to the time available. In this case, I think it relates both to workload and expectations.

I: Ehm, how is it organized throughout the year, when it comes to tests and such?

Bjørnsen: Er… they have… (1.0) Er… (1.0) independent of course, if it runs one year or, er… like [mathematics Y] runs throughout a year. Er… (2.0) [MA-X], [mathematics X] runs throughout a semester, but they have a test every forth week. So that is three per semester. Er… They count on the grade. And then in… (1.0) [Mathematics Y] they have a digital exam. Could call it a midterm, or what have you, er… (0.5) but it is an exam, right, er (1.0) considering you have to show up and show ID. It is digital, and then they have a final paper exam, while [math X] has (0.5) the three assignments and one (0.5) final paper exam.

I: I see. Ehm… (0.5) so, to summarize, what resources… *legger dere opp** for them to use?

*Translation note: The Norwegian term *å legge opp* is derived from the volleyball term for delivering a setter (a pass leading into a smash). It refers to doing an action X that you expect for someone else to respond to with a specific action Y. The expression is used when the other person have a freedom to choose, but it will be obvious to them that you performed action X with the assumption that they would then perform action Y.

Bjørnsen: Er it… (0.5) in my courses, er… (1.5) it is… videos. And… MyLabs and Mastering, right, or MyMathLab, which also… I use them interchangeably. So it is pretty much those that, initially are (1.0) er, like the basics, but I do give them – I put out links, for instance, SimReal, which is the tool that [Birkeland] develops. Er, where I do not have any control over, really whether they use it. Ehm… (2.0) and… [coughs] there are some links to help pages, like Mathcenter in – in… (1.5) in England. Where they – where I have showed them, just that if you go there you can find alternative videos, you can find, like leaflets with, like (1.0) cards er, presentation of the different topics and so on. I do not think they use it that much. Ehm (1.5) and then I have… (1.0) I put out links to – considering there is a lot of repetition, I put out links to er… math pages on…

(1.0) Cappelen, The Sinus books, which have a lot of videos for all the topics. Er… Exercises in Norwegian and so on. Ehm (0.5) so (1.5) But I – again, I think that most (0.5) they (0.5) work on (0.5) MyLabs exercises and so on.

[Talks a bit about plans for future courses]

I: I see. Okey, thank you – unless there is anything (0.5) else you want to (0.5) add?

Bjørnsen: No. I think we have been through… (1.0) through it, again I… (1.0) Like I tell my students… (2.0) It is organized with a lot of freedom, so… (1.0) in a way organized such that I have used my web resources, right, where (0.5) one works independently of time and space, but I probably will have lectures, will have – recommend that they attend, but er… (1.5) like I said, it is up to them. They have to put in the work.

[I finish the interview]

Original:

[Før intervjuet forklarer jeg litt hva jeg er interessert i]

Bjørnsen: Det som jeg gjør er jo på en måte at de… (1.0) ehm… (1.0) de har det jo for så vidt veldig fritt, ved at opplegget ligger – de kan egentlig starte i Canvas og så starte uke én og jobbe seg nedover punktene. Og bla, bla, bla, det (1.0) altså… (1.0) Og der ligger det lenker til videoer, det ligger lenker til det fagstoffet de skal ha, eh (1.0) og… lenker til de testene de bør gjøre, eh, hjemmearbeidet de bør gjøre hvis de vil gjøre det online. De kan også gjøre det ifra lærebok, for læreboka ligger i bunnen. Eh, så de må ikke gjøre ting online. Eh… (1.0) så det er basisen, ogs… – men så har jeg også… (1.0) Ehm (0.5) så har jeg (0.5) da i begge fagene (1.5) så har jeg kjørt to timer forelesning i uka, som jeg ikke gjorde før. Eh (0.5) og det (1.0) og da foreleser jeg egentlig ikke sånn som jeg gjorde, eh… (1.0) tradisjonelt, før. For det jeg har gjort nå er at jeg tar ut hovedpunktene av det vi skulle hatt, og så går jeg gjennom og kanskje går jeg gjennom et eksempel, så sier jeg, ‘dette er det viktige, dette er det dere skal få med dere’. Og så ha… – (1.0) hvis du tar (1.0) [Ma-x], så har jeg gitt de gruppearb… – gruppeoppgaver som de skal jobbe med, eh… (1.0) som er relevante i forhold til papireksamen, for de har jo ikke hatt papireksamen før de

(0.5) som går i andreklasse nå. Så den skal de ha i morgen, så det blir spennende å se hvordan de gjør det der. Eh (1.0) og det kommer jeg til å gjøre i [Ma-y] nå etter jul. Og før jul nå, så var det jo [Berntsen] som hadde forelesningene, så da lot jeg henne… 'da gjør du det du synes er fornuftig i forelesningene'. Men jeg regner med at hun… (2.0) eh, eller (0.5) at hun også tar ut hovedpunktene og essensene av det de skal (0.5) ha vært gjennom hver uke. Ehm (2.0) og [kremter] og så er det – de får – hver uke så får de (1.0) ehm… oppgaver fra læreboka. Eller så kan de gå inn og gjøre det i mylabs, online. Det er jo valget som de gjør. Og så har de deltester som teller på e… – karakteren. Tre i semesteret.

I: Ja. Ehm (0.5) jeg har hørt også en av de som jeg har intervjuet si «mylabs», er det bare en forkortelse av (1.0) det fulle navnet, eller er det noe eget?

Bjørnsen: [Ler] Eh… nå heter det «mylabs and mastering», eh, men det er jo egentlig ikke noe annet enn… eh… samme type oppgave som du har i læreboka, som ligger online, eh, hvor det er administrerte tall, eh… (1.0) og de kan da velge å… (0.5) hvis de er inne og jobber i *homework* som det heter, så kan de ta og jobbe med en oppgave og så 'jeg vil ha en tilsvarende, lik oppgave', så får de en ny en, og når de skriver inn svar så får de umiddelbar feedback på om det er riktig eller galt.

[Jeg spør ham for ordents skyld om det pleide å hete mymathlabs, siden de to deltakerne sier forskjellig, og han sier at det er ulike navn på det samme avhengig av hva du får tilgang til det gjennom]

I: Så hvordan blir en vanlig uke (1.5) vil du si?

Bjørnsen: Ehm… (1.0) Jeg t… – ja, en vanlig uke er jo, jeg t… – (2.0) de jobber jo litt forskjellig, en del av disse studentene. Eh… (1.0) Det er jo – jeg vet jo… (0.5) jeg har snakket med noen (1.0) som sier at veldig mange av de som går på elektro, de velger å bli sittende i elektrolabben, hvor – på en måte er hjemmet de sitt, selv om det er (1.0) to rom bortenfor, så sitter de der i stedet for å sitte der jeg er når de har øvinger for eksempel. Så jeg har vel (1.0) sånn i snitt i [Ma… (1.0) x] (1.5) så ligger det på sånn rundt ti av… (1.0) trettito-tre som – som kommer i (1.0) lokalet hvor jeg sitter. Eh, men jeg vet jo at de andre, de sitter jo borti (2.0) det andre lokalet og det er jo ikke alltid de jobber med matte når de (1.5) har mattetimer også videre, men sånn (1.0) ehm… (0.5) elektro har en del labb, og de har en del fag hvor de har prosjekter i – så det – de er kanskje litt eh… Altså… (2.0) De s… – jeg merker jo når de har prosjekter at da faller de på en måte ut fra matematikken og holder på med (0.5) elektrofagene og så merker jeg når de har… (0.5) før testene og sånn så er det mer… (1.5) kan det være mer trykk da. Og så er det (1.0) som det alltid er i – uansett hvilket fag jeg har, i [Ma-y] første – altså [Matte Y], så… (1.0) Ehm… (2.0) har jeg – [Berntsen] som har hatt forelesningene, og så har jeg hatt [Bøe] som har tatt to timer og så har jeg hatt to timer (0.5) som bare er ren øving, og de var… (1.0) Eh, de to siste timene på torsdagen, da er det ikke mange som kommer. Da sitter de faste (0.5) 4-5 stykkene som (2.0) som er der, men igjen så sier de at en del av de sitter inne i elektrolabben. (3.5) Ja. Og det (1.5) eh… s… – jeg kan merke litt forskjell på temaene også. I [Ma-y] så er det mye repetisjon, og da (1.0) eh, tror de vel kanskje at de kan det. Og så kommer de til komplekse tall som de ikke har hatt, og da er det flere som er der også videre.

I: Ehm, hvordan er det lagt opp gjennom året, i forhold til tester og sånne ting?

Bjørnsen: Eh… de har… (1.0) Eh… (1.0) uavhengig av fag om det går et år eller, eh… altså [matematikk y] går jo over ett år. Eh… (2.0) [Ma-X], [Matematikk X] går over ett semester, men de har en test hver fjerde uke. Så det blir tre i semesteret. Eh… De teller på karakteren. Og så har jo… (1.0) [Matematikk Y] de har en digital deleksamen. Kan jo kalle det tentamen, eller hva du vil, eh… (0.5) men det er jo en eksamen da, eh (1.0) i og med at de må møte opp og vise kort. Den er digital, og så har de en avsluttende skriftlig papireksamen, mens [matte X] har (0.5) da de tre deltestene og en (0.5) avsluttende skriftlig papireksamen.

I: Ja. Ehm… (0.5) så, sånn for å oppsummere, hvilke ressurser… legger dere opp til at de bruker?

Bjørnsen: Eh det… (0.5) i mitt fag, så eh… (1.5) er det… videoer. Og… mylabs and mastering, da, eller mymathlab, som da også… jeg bruker det om hverandre. Så det er liksom de som, i utgangspunktet, er (1.0) eh, liksom basisgreiene, men jeg gir de jo – jeg legger jo ut lenker til, for eksempel, Sim real, som er det verktøyet som [Birkeland] utvikler. Eh, der har jeg ikke noe kontroll på egentlig om de bruker noe av det. Ehm… (2.0) og… [hoster] det ligger noe lenker til noe hjelpesider, sånn som Math Center i – i… (1.5) i England. Hvor de – hvor jeg har vist de, bare, at hvis du går inn her kan du finne alternative videoer, du kan finne sånn leaflets med, sånn (1.0) kort eh, presentasjon av de forskjellige emnene også videre. Jeg tror ikke de bruker det så mye. Ehm (1.5) og så har jeg… (1.0) Så legger jeg ut lenker til – i og med at det er en del repetisjon, så legger jeg ut lenker til eh… fagsider på… (1.0) Cappelen, Sinus-bøkene som har masse videoer til alle temaer. Eh… oppgaver på norsk, også videre. Ehm (0.5) så (1.5) Men jeg – igjen så tror jeg de fleste (0.5) de (0.5) jobber med (0.5) mylabsoppgavene også videre. [Forteller litt om planer for fremtidig gjennomføring av kursene].

I: Ja. Okey, tusen takk – eller med mindre det var noe (0.5) mer du ville (0.5) legge til?

Bjørnsen: Nei. Tror vi har vært igjennom… (1.0) Igjennom det, igjen så… (1.0) Som jeg sier til studentene mine, så… (2.0) så er det jo egentlig lagt opp helt fritt, altså det… (1.0) på en måte lagt opp som sånn som jeg har kjørt nettkursene mine, ikke sant, hvor (0.5) en jobber uavhengig av tid og sted, men jeg kommer nok til å forelesningstimer, kommer til å ha – anbefaler jo at de er der, men eh… (1.5) det er som sagt opp til de. Det er de som må gjøre jobben.

[Jeg avslutter intervjuet]

Appendix H: Interview with Christensen

Following is my translation, as well as the original transcription of the interview I conducted with Christensen in January 2018

Translation:

[Prior to recording, I explained the three sub-questions included in the question]

I: Well, can you tell me a little bit about the course?

Christensen: Yes. [Mathematics X] is the first math course that civil engineers at [Charlie] take. All civil engineers at [Charlie] must take [Mathematics X]. And it is a continuation of what one calls R2 in upper secondary. The topics here are single variable calculus, clear and simple.

I: (4.0) And (1.5) how is (0.5) it organized throughout the year?

Christensen: So [Mathematics X] has, er… after a – our institute has a so-called innovative education project – gotten a new structure. Rather than four… er, lectures, that is four times 45 minutes, possibly considered two double-hours, right, which it is, (1.5) one has – for every parallel one has divided it into what we call overview lectures and interactive lectures. So the overview lectures are, as the name implies, there is an overview of the week's topic. It takes place with as large crowds as we can manage. The interactive lectures are partially based on the *flipped classroom* principle, (1.0) er, but where we… have… focused the instruction in relation to some choice exercises. So, then the idea here is that… we want to get more interaction with the students, understand what they struggle with, what goes wrong, er, which topics invite… misconceptions and so forth. And we have tried to achieve that by… giving them some exercises where they get time to do exercises throughout the lecture, but they also get to see a solution. They can ask for help (0.5) with the exercises, along the way, and we can also walk around in the lecture hall, so i… –the interactive lectures are designed for a maximum of er… 180 students. So it is still a pretty large crowd, but it is considerably smaller than the overview lectures, which have up to five hundred at a time. So each student who takes [Mathematics X] are intended to follow one overview lecture and one interactive lecture a week.

I: I see. Er, beyond that, how do you consider a normal (1.0) week for the students may look?

Christensen: I will guess that an ordinary week for the students consists of them attending an overview lecture, an interactive lecture and that they hopefully stop by the math lab which is a… Well, we call it *student support center* for mathematics, which is open all week long. The students have some so-called priority hours, but in principle they can meet up whenever they want, within opening hours, (1.5) and the opening hours are quite long. In addition I would assume that… a considerable portion of the students use our last service, which is what we call plenary, where (1.0) a person at the institute more or less stand and work through exercises for them. Ideally, I would wish for the students to also make use of the digital resources we have er… developed, be it videos or web pages and so on, but er… I do not know how much it is used by the students, I think some use them eagerly, but others barely know of their existence.

I: So beyond that, which resources do you (1.0) ehm, put out or *legger opp til**?

*Translation note: The Norwegian term *å legge opp* is derived from the volleyball term for delivering a setter (a pass leading into a smash). It refers to doing an action X that you expect for someone else to respond to with a specific action Y. The expression is used when the other person have a freedom to choose, but it will be obvious to them that you performed action X with the assumption that they would then perform action Y.

Christensen: Well, every… week we put out the interactive exercises several days in advance of the interactive lecture, so students do have an opportunity (1.0) to prepare ahead of time for the interactive lecture. That happens quite seldom, is my impression. Parallel to that we each week have a so-called Maple TA test. It functions as a part of the weekly (1.0) er… completion they need to (0.5) be allowed to take the exam, so we put out twelve Maple TA tests throughout a fourteen week long semester. They must complete six out of twelve to take the exam. To make it more attractive to do those Maple TA tests we have chosen to let them count into a folder evaluation, that is, that each Maple TA test that is approved (1.5) gives them one point in the folder, but with a maximum of ten points. The last ten points for the folder come from what we have called written assignments, which are… assignments that span a three week period, so they get the exercises three weeks, approximately, before the deadline, and then they deliver it in, er… *gjerne** hand-written documents, but that are scanned and sent as pdf files. In addition to that we have what we… call recommended exercises, which are exercises they are not (1.0) asked to deliver, but where they can get a solution, typically in the form of a written solution suggestion, but also in the form of going through solutions in the so-called plenary. On the topics pages we include not only theory, but we also include… completely solved examples and… er… there as well, tips about which exercises they could do, so it is quite an expansive *tilbud**.

*Translation note: *Gjerne,* followed by an option, implies something about how suitable the option is. It can be used to mean the preferred option. It can also mean that despite common assumption, it is one of the acceptable options. I think the latter is the case here.

**Translation note: *Tilbud* may mean either an optional service or (as here) a collection of offered services provided within a given context, for instance a university course.

I: And what about more traditional… like a textbook and such resources?

Christensen: Yes, we have a textbook [textbook title] and… (1.5) we have used it for a couple of years. My impression after talking to the clerk is that it… there is a lot of circulation on the secondary marked, so I think that book (1.0) is bought and sold again, so I do not know if the students use it that frequently. Things indicate that they do not, if they sell it again. Er (0.5) the textbook is in English, we get some comments on that. Students think that reading mathematics in English is a challenge, and personally I believe that we have a tendency to overestimate how proficient our students are in English.

I: (4.0) I see. Ehm, is there anything else you would like to mention, or should we finish?

Christensen: Ehm. I guess I can say that er… (0.5) from our perspective we experience the restructuring to interactive and overview lectures as, er, successful, in the sense that we think we know that the students are more satisfied with the structure. It is always a bit scary to say whether it leads to better results. For that, there are too many variables in play, that is, we have the exam itself, which naturally is quite influential. But then we also have, er… (0.5) that the exam tasks over time become quite similar if it is the same person that is involved all the time, that is hardly avoidable. So it is hard to predict if this has a positive effects on them – on the exam results, but one can hope. Er… Another aspect we are, er… interested in is to… to monitor students' digital habits, because, er (1.5) it seems like… to have a… a textbook might be something that in ten years time we might not have, and maybe even sooner than that, and we are – we are interested in the possibilities to further develop our digital resources, right, and (1.0) turn it into, if not a full fletched textbook, then at least a powerful supplement. So that is a thing for… for the future, but that we are (0.5) interested in.

[I finish the interview]

Original:

[Før intervjuet forklarer jeg litt hva jeg er interessert i]

I: Ja, kan du fortelle litt om kurset?

Christensen: Ja. [Matematikk X] er det første matematikkurset sivilingeniørstudenter ved [Charlie] tar. Alle sivilingeniørstudenter ved [Charlie] må ta [Matematikk X]. Og det er en fortsettelse av det man i videregående skole i dag kaller R2. Temaene her er envariabel kalkulus, kort og greit.

I: (4.0) Og (1.5) hvordan er (0.5) det lagt opp sånn gjennom året?

Christensen: Så [Matematikk X] har, eh… etter et – instituttet vårt hadde et såkalt innovativt utdanningsprosjekt – fått en ny form. I stedet for fire… eh, forelesninger, altså fire ganger 45 minutt, eventuelt sett på som to dobbelttimer, da, hvilket det jo er, (1.5) har man – for hver parallell så har man delt det opp i det vi kaller oversiktsforelesninger og interaktive forelesninger. Så oversiktsforelesningene er som navnet tilsier, det er en oversikt over denne ukens tema. Det foregår i så store forsamlinger som vi får til. De interaktive forelesningene er delvis basert på *flipped classroom*-prinsippet, (1.0) eh, men der vi… har… fokusert undervisningen knyttet til noen bestemte oppgaver. Så tanken er her da at… vi ønsker å få mer interaksjon med studentene, forstå hva de sliter med, hva går greit, eh, hvilke tema byr på… misforståelser også videre.

Og det har vi da prøvd å få til ved å… gi dem noen oppgaver hvor de får tid til å regne på oppgavene underveis i forelesningen, men de får også se en løsning. De kan be om hjelp (0.5) underveis til oppgavene, og vi kan også gå rundt i forelesningssalen, så i… – de interaktive forelesningene er lagt opp til maksimum eh… 180 studenter. Så det er fortsatt en ganske stor forsamling, men det er betydelig mindre enn oversiktsforelesningene, som er oppmot fem hundre (1.0) om gangen. Så hver student som tar [Matematikk X] er tenkt til å følge en oversiktsforelesning og en interaktiv forelesning i uken.

I: Ja. Eh, utover det, hvordan tenker du at en vanlig (1.0) uke for studentene ser ut?

Christensen: Jeg vil tippe at en vanlig uke for studentene består av at de går på en oversiktsforelesning, en interaktiv forelesning og at de forhåpentligvis er innom det vi kaller mattelabben, som er et… ja vi kaller det *student support center* for matematikk da, som er åpent hele uken lang. Studentene har noen såkalte prioriterte timer, men i prinsippet kan de møte når de vil, innenfor åpningstimene, (1.5) og det er ganske lange åpningstider. I tillegg vil jeg anta at… en betydelig andel av studentene er innom (0.5) vårt siste tilbud som er det vi kaller plenumsregning, hvor (1.0) en person ved instituttet mer eller mindre står og regner oppgaver for dem. Ideelt sett ville jeg ønsket at studentene også gjorde bruk av de digitale ressursene vi har eh… utviklet, være seg videoer eller nettsider også videre, men eh… jeg vet jo ikke hvor mye dette er i bruk blant studentene, jeg tror noen bruker det veldig flittig, men andre vet knapt om dens eksistens.

I: Så utover det, hvilke ressurser er det dere (1.0) ehm, legger ut eller legger opp til?

Christensen: Ja, vi legger ut hver… uke de interaktive oppgavene flere dager i forkant av den interaktive forelesningen, så studentene har da mulighet (1.0) til å forberede seg forut for den interaktive forelesningen. Det skjer i veldig liten grad, er mitt inntrykk. Parallelt med det så har vi hver uke en såkalt Maple TA-test. Dette inngår som en del av den ukentlige (1.0) eh… gjennomføringen de må gjøre for å (0.5) få lov til å ta eksamen, så vi gir ut tolv Maple TA tester i løpet av et fjorten uker langt semester. De må fullføre seks av tolv for å ta eksamen. For å gjøre det litt mer attraktivt å gjøre disse Maple TA-testene så har vi valgt å la de telle inn i en mappeevaluering, det vil si at hver Maple TA-test som blir godkjent (1.5) gir dem ett poeng inn i mappen, men maks 10 poeng. De siste 10 poengene fra mappen kommer fra det vi har kalt skriftlige innleveringer, som er… innleveringer som strekker seg over en tre ukers-periode, så de får oppgavene tre uker sånn cirka før fristen utløper, og hvorpå de da leverer inn, eh… gjerne håndskrevede manuskripter, men som er scannet og sendt i et system som pdf-filer. I tillegg til alt det så har vi det vi… kaller anbefalte oppgaver, som er oppgaver de ikke (1.0) er bedt om å levere inn, men hvor de kan få se en løsning, typisk i form av et skriftlig løsningsforslag, men også i form av gjennomgåtte løsninger i den såkalte plenumsregningen. På temasidene så inkluderer vi ikke bare teori, men vi inkluderer også… fullstendig løste eksempler, og… eh… også der tips om hvilke oppgaver de kan gjøre, så et veldig omfattende tilbud vi har.

I: Og hva med mer tradisjonelle… sånn læreboka og sånne ressurser?

Christensen: Ja, vi har en lærebok [Lærebok] og den… (1.5) har vi brukt i et par år. Mitt inntrykk etter å ha snakket med bokhandleren er at det er… det er mye sirkulasjon på bruktmarkedet, så jeg tror den boken (1.0) kjøpes inn og blir solgt igjen, så jeg vet ikke om studentene bruker den så flittig. Ting kan jo tyde på at de ikke gjør det, hvis de selger den igjen. Eh, (0.5) læreboken er på engelsk, det får vi en del kommentarer på. Studentene synes at det å lese matematikk på engelsk er en utfordring, og personlig mener jeg nok at vi har en tendens til å overvurdere hvor sterke studentene er i engelsk.

I: (4.0) Ja. Ehm, er det noe mer du vil nevne, eller skal vi runde av?

Christensen: Ehm. Jeg kan vel si det at eh… (0.5) sett fra vårt perspektiv så opplever vi vel denne omleggingen til interaktive og oversiktsforelesninger som, eh, som vellykket, i den forstand at vi syns å vite at studentene er mer fornøyd med opplegget. Det er alltid skummelt å si noe om det medfører bedre resultater. Til det er det for mange variabler i spill, altså man har selve eksamen som er selvfølgelig svært utslagsgivende. Men så har man også, eh… (0.5) at eksamensoppgavene over tid vil jo bli delvis ganske like hvis det er samme person involvert hele tiden, det er nesten ikke til å unngå. Så det er vanskelig å spå noe om dette har positiv effekt på de – på eksamensresultatene, men det er lov å håpe. Eh… En annen ting vi er, eh… interessert i er jo å… å kartlegge studentenes digitale vaner, for, eh (1.5) det virker som… å ha en… en lærebok, er kanskje noe vi ikke vil ha om en ti års tid eller kanskje til og med mindre enn det og, så vi er – vi er interessert i å se på mulighetene for å videreutvikle våre digitale ressurser da, og (1.0) gjøre det om til, om ikke en fullgod lærebok, så vært fall et ganske kraftig supplement da. Så det er jo en ting for… for fremtiden, men som vi da er (0.5) interessert i.

[Jeg avslutter intervjuet]

Appendix I: All excerpts used in the thesis

Within this appendix, some context is given for the excerpts used in the thesis. This additional context can involve the text immediately prior and following the excerpt and a description of the question that the students made their statements in response to. In this appendix, the excerpts are written in the long form from Appendix E.

From pilot interview

<table>
<tr><td>Quote location:
Per</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
Like, it is incl… repetition of material and then here too, right [pointing at learning new material]. I think that, you work with exercised to learn it, right… the new material as well.

Original:
Asså, det går jo… repetisjon av stoff og det går her også da [peker på innledning av stoff]. Tenker at, ja, du jobber jo med oppgaver for å lære det… det nye stoffet i tillegg.</td></tr>
<tr><td colspan="2">Context:
His mind map was divided into learning new material and repetition of material. He mentioned exercises in his description of his mind map, and was asked whether it was included within repetition of material.</td></tr>
</table>

From interviews with Adrian

<table>
<tr><td>Quote location:
Adrian 1,2</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
If I work with others, then they are also (0.5) resources… in a way. Ehm (1.0) If we are several, then it is (1.0) quite nice, because then you can (1.0) get them to check if you have done some idiotic things along the way and that is why your answer is wrong. That one has (1.0) dropped… dropped a parenthesis or something, or... (0.5) forgot the sign. And it is – usually if something goes wrong, that is the kind of error it is, so (1.5) can be very nice to have several people who… who reads it over (1.5) if you do not quite get what you have done wrong, and then it is also the issue that if you are completely stuck it is also… nice to (1.0) have some other people nearby who can at least point you in (0.5) the right direction.

Original:
Hvis jeg jobber med andre, så er jo de også (0.5) ressurser… på et vis. Ehm (1.0) Hvis vi er flere, så er det jo (1.0) det er jo veldig greit, for da kan man jo (1.0) få dem til å sjekke om du har gjort noen idiotiske ting underveis så det er derfra svaret blir feil. At man har (1.0) mista… mista en parentes eller noe, eller... (0.5) Glemt fortegn. Og det er – som regel hvis noe skjer feil så er det jo den typen feil det er, så… (1.5) kan være veldig greit å ha flere personer som… som leser litt over (1.5) hvis du ikke vet helt skjønner hva du har gjort galt, også er det jo hvis du er helt fast, så er det jo også… greit å (1.0) ha noen andre personer i nærheten som kan i alle fall peke deg inn på (0.5) rett spor.</td></tr>
<tr><td colspan="2">Context:
To the previous question, mentioned that he used more resources when he found it difficult. Was asked to elaborate on resources used when it was easy and difficult. This is the last half of his answer. The first half involves his answer for when he works alone.</td></tr>
</table>

Quote location: Adrian 1,5	**Quote categorization**: Unprompted
Translation: I: Yeah. (2.0) So, the resources you use, like (1.0) how have you come across them? A1: (5.0) GeoGebra, I believe we started using it back in (0.5) upper secondary. Then it was (1.0) mostly a very useful tool and I think there were some test and (0.5) and such where we more or less had to use GeoGebra, or (0.5) or similar tools. It was either that or to (1.5) draw the graphs you made on the calculator. […] Let me see – calculator. When I had R1 and R2 in secondary, I (0.5) was told that Casio's FX 9860GII, was the calculator to get, and… So I bought it and then I have had it since, so… that is very – a very good calculator. There are – there are not many calculators that do very much more that we get – get to bring to the exams anyway. Original: I: Ja. (2.0) Så, ressursene du bruker, sånn (1.0) hvordan har du funnet frem til de? Adrian: (5.0) Geogebra det mener jeg at vi begynte med allerede på (0.5) videregående. Da var det (1.0) først og fremst et veldig nyttig verktøy og jeg tror at det var noen sånn der tester og (0.5) og sånn der man mer eller mindre måtte bruke geogebra eller (0.5) eller et liknende verktøy. Det var vel enten det eller å (1.5) tegne opp grafene du lagde på kalkulatoren. […]Skal vi se - kalkulator. Når jeg hadde R1 og R2 på videregående så (0.5) ble vi jo fortalt at Casio sin FX 9860G2, det var kalkulatoren å få, og… Så kjøpte jeg den og så har jeg jo hatt den siden, så… det er jo en veldig – veldig grei kalkulator. Det er jo – det er jo ikke mange kalkulatorer som gjør så veldig mye mer som vi får med – å ha med på eksamen uansett.	
Context: The start and end of Adrian's answer included. About 60% of the answer is missing, where he discusses Wolfram Alpha and Rottmann's formula collection.	

<table>
<tr><td>Quote location:
Adrian 1,6</td><td>Quote categorization:
Semi-prompted</td></tr>
<tr><td colspan="2">Translation:
Of course, when it comes to human resources, then er… I work along others, not just because things get easier, but also because it is pleasant, because it is social and such and (0.5) strengthens the social…

Original:
Selvfølgelig, når det er snakk om menneskelige ressurser, så eh… jobber jeg jo i lag med andre, ikke bare fordi ting blir enklere, men fordi det er hyggelig, fordi det er sosialt og sånt og (0.5) styrker det sosiale…</td></tr>
<tr><td colspan="2">Context:
Asked whether what resources he liked influenced how much he used them. This is at the end of his answer.</td></tr>
</table>

<table>
<tr><td>Quote location:
Adrian 1,7</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
It is (1.0) how well-suited it is for the purpose I have for it. And then it is also (1.0) how cheap it is. Ehm (1.0) For instance, that is why I have not (0.5) paid for Wolfram Alpha and such, and (1.0) and at (0.5) the times I do not get like (1.5) when I do not get it from school, I do not have Matlab installed because it is quite… quite an expensive program. Even though it would be very… very convenient for certain things, I have not used it (0.5) in the math course, so… but there are (1.0) there are many (0.5) clever things you can do in Matlab as well. Ehm… (1.5) Well, it is (0.5) how (0.5) well, how suited it is for the purpose, how available it is… ehm… (1.0) And then, of course, to an extent how comfortable I am with it. It… (3.0) Abaci are both very practical and simple, but I have not used them, so then I will not use them either, so…

Original:
Det er jo (1.0) hvor velegna det er til formålet jeg har for det. Også er det jo også (1.0) hvor økonomisk det er. Ehm (1.0) Det er jo blant annet derfor jeg ikke har (0.5) betalt for Wolfram Alpha og sånn, og (1.0) Og at (0.5) de tidene jeg ikke har noe sånn (1.5) De tidene jeg ikke får av skolen, så har jeg heller ikke matlab installert for det er jo et ganske… ganske dyrt program. For det om det kan være veldig… veldig kjekt for enkelte ting, men jeg har jo ikke brukt det (0.5) til matematikkfaget så langt, så… men det er jo (1.0) Det er jo veldig mange (0.5) finurlige ting du kan gjøre i matlab også. Ehm… (1.5) Nei det er jo (0.5) hvor (0.5) ja, hvor velegna det er for formålet, hvor tilgjengelig det er… ehm… (1.0) Og så er det jo også, selvfølgelig, en grad av hvor komfortabel jeg er med det. Det… (3.0) Kuleramme er jo både veldig praktisk og veldig enkelt, men jeg har jo ikke brukt de, så da kommer jeg heller ikke til å bruke de, så…</td></tr>
<tr><td colspan="2">Context:
Asked what influences what resources he used. This is the entirety of his answer.</td></tr>
</table>

Quote location: Adrian 1,9	**Quote categorization**: Unprompted

Translation:
Ehm (1.5) when it comes to… (1.5) quite (1.0) quite simple vector calculation (1.0) then it is (0.5) usually simple enough that I don’t use resources, but… (0.5) except from pencil, paper and maybe calculator, but as soon as it comes to things like that you have (1.5) all those points, check that it does not lie on – or that – Check if all the points lie (1.0) Er, on this and that geometric object, defined by (1.0) those three points, of the four points. Then it might be really nice to just stick it into GeoGebra when one is done, and then che… – see that (0.5) ‘oh, no wait, that point, it was actually not (0.5) in… on that plane’ and so on. Ehm… (1.0) So… (1.5) when it comes to a bit more complicated things where you feel you have to double check, where it is not immediately obvious what is right, then it is – I do use more resources then (1.0) on simpler (0.5) topics.

Original:
Ehm (1.5) når det er snakk om… (1.5) helt (1.0) helt enkel vektorregning (1.0) så er det jo (0.5) som regel enkelt nok til at jeg ikke trenger noen ressurser, men… (0.5) bortsett fra penn, papir og kanskje kalkulator, men med en gang det kommer til ting som at du har (1.5) alle disse punktene, sjekk at den ikke ligger på – eller at – sjekk om alle punktene ligger i (1.0) Eh, dette og dette geometriske objektet, dannet av (1.0) disse tre punktene her, av de fire punktene. Da kan det jo være veldig greit å bare smeise det inn i geogebra når man er ferdig, og så sjekk… – ser man at (0.5) oi, nei vent, det punktet det lå faktisk ikke (0.5) på… i planet og så videre. Ehm… (1.0) Så… (1.5) når det kommer til litt mer sånn kompliserte ting der du føler at du må dobbeltsjekke, der det ikke er umiddelbart åpenbart hva som er rett, så er det jo – benytter jeg meg mer av ressurser enn (1.0) i litt enklere (0.5) tema.

Context:
Asked whether his use of resources varied from topic to topic. This is at the start of his answer and constitutes approximately 40% of his answer. He also mentions using pencil and paper rather than the calculator’s polynomial function. He ends by mentioning that he can use GeoGebra for functions and polynomials, but nor for differential equations.

Quote location: Adrian 2,1	**Quote categorization**: Prompted

Translation:
I: First I have written that (1.0) er, when there is a new topic, then (1.0) you assess whether you need more resources for the problem or the most basic. That you (0.5) prefer to do things on paper if possible, for instance rather than polynomial functions on the calculator. Ehm… (0.5) that you have several resources linked to checking answers, for instance graph tools in GeoGebra, talking with fellow students and Wolfram Alpha, but you have not used the latter that much. And… you said you get a lot of use from Rottmann's formula collection.
A1: Yes. That is correct.

Original:
I: Først så har jeg skrevet at (1.0) eh, når det er nytt stoff så (1.0) vurderer du om du trenger flere ressurser til problemet eller bare det enkleste. At du (0.5) gjerne tar ting på papir om det er mulig, for eksempel i stedet for å bruke polynomverktøy på kalkulatoren. Ehm… (0.5) at du har flere ressurser knyttet til å undersøke svar, for eksempel grafverktøy geogebra, samtale med medelever og Wolfram Alpha, men du har ikke brukt sistnevnte så mye. Og… du sa at du har mye nytte av Rottmanns formelsamling.
A1: Ja. det stemmer.

Context:
Preceded by an explanation that the interviewer is attempting to summarize Adrian's statements from the first interview. When later asked specifically for any resources he used more or less, said that in a statistics course he took, he used calculator more.

<table>
<tr><td>Quote location:
Adrian 2,4</td><td>Quote categorization:
Semi-prompted</td></tr>
<tr><td colspan="2">Translation:
I: Ehm. (3.0) Let me see. (1.5) So, when it comes to (0.5) doing things your own way, you last mentioned (1.0) that you had (0.5) discovered 3D-graphics in GeoGebra on your own. Ehm, is there more you would add (1.0) from lately.
A1: (4.0) Well, no, not really, have not done very much new since the last time, so… (1.0) Have nothing of it in math, really.

Original:
I: Ehm. (3.0) La meg se. (1.5) Så, når det gjelder å (0.5) gjøre ting til dine egne, så nevnte du sist (1.0) at du hadde (0.5) oppdaget 3D-grafikken i geogebra på egen hånd. Ehm, er det noe mer du vil legge til (1.0) nå i det siste.
A1: (4.0) Ja, nei, Ikke egentlig, har ikke gjort så veldig mye nytt siden forrige gang, så… (1.0) Har ikke noe av det i matte, egentlig.</td></tr>
<tr><td colspan="2">Context:
It was established at the start of the interview that the interviewer gave various summaries of Adrian’s answers from the previous interview.</td></tr>
</table>

<table>
<tr><td>Quote location:
Adrian 2,5</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
I: I see. Ehm (1.0) about (0.5) working with others you said last time that you are a group who (0.5) potentially sit and work and that it varies from two to five how many who sit there. Is it mostly the same, or…?
A1: Well, have been a bit busy lately, with work and such in [neighboring town], so it has not been (0.5) as often as I would wish but I think that (0.5) the rest of the group are to take on a math assignment later today, actually, but [inaudible] to [neighboring town], because I have both work there and a hairdresser appointment.

Original:
I: Ja. Ehm (1.0) om (0.5) å jobbe med andre så sa du sist at dere er en gjeng som (0.5) eventuelt sitter og jobber og at det varierer fra 2 til 5 hvor mange som sitter der. Er det stort sett det samme, eller…?
A1: Ja, har vært litt travelt i det siste med mye jobb og sånn i [Naboby], så det har ikke vært (0.5) like ofte som jeg skulle ønske, men jeg tror at (0.5) resten av gjengen de skal gå løs på matteinnlevering faktisk senere i dag, men den [uforståelig] til [Naboby], for der har jeg både jobb og en frisørtime.</td></tr>
<tr><td colspan="2">Context:
It was established at the start of the interview that the interviewer gave various summaries of Adrian’s answers from the previous interview.</td></tr>
</table>

<table>
<tr><td>Quote location:
Adrian 3,1</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
Well, I have transitioned a bit from working with (0.5) assignments to exam problems and such, but (1.0) the resource use itself has (0.5) been the same. Of course, at exam tasks when I am (0.5) attempting them, I of course do not use (0.5) internet and talking with friends and such until I am done, because then the thing is to test oneself a bit first, then it is just (0.5) calculator and… (1.5) er… (0.5) pencil and paper and (2.0) or, formula collection that is allowed.

Original:
Ja, jeg har jo gått litt fra å jobbe med (0.5) innleveringsoppgaver til eksamensoppgaver og sånn, men (1.0) selve ressursbruken har jo (0.5) vært det samme. Selvfølgelig, på eksamensoppgavene når jeg skal (0.5) prøve på dem så tar jeg jo ikke og bruker (0.5) internett og snakke med venner og sånn før etter jeg er ferdig, for da da er det jo liksom å teste seg selv litt først, da er det jo kun (0.5) kalkulator og… (1.5) Eh… (0.5) penn og papir og (2.0) eller, formelsamling som er lov.</td></tr>
<tr><td colspan="2">Context:
Asked to see if he would like to make any changes to his mind map from the previous interview. This is at the start of his answer. Afterwards, he realizes that he has not included a formula collection in his mind map and talks about a new formula collection he uses.</td></tr>
</table>

<table>
<tr><td>Quote location:
Adrian 3,3</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
Ehm… (1.5) I have not used, er… (1.0) GeoGebra that much for mathematics, I have used it for (0.5) statistics, actually, because it has very many nice tools for binomials (1.0) er (0.5) all probability distributions, actually, but (0.5) has not been much geometry recently. So I think that I am going to use it more when I really start the final preparations for exams, but (1.0) right now I am studying a bit for… for programming exams, which is in two days. So… (2.5) yeah, er (3.0) Have not been to (0.5) lectures for the last (1.0) week. Ehm… (3.0) So it has mostly been individual work. Has not actually been much math at all for the last weeks. Er… (1.0) because I am busy studying for other exams, but it has been a bit now and then.

Original:
Ehm… (1.5) Jeg har ikke brukt eh… (1.0) geogebra så veldig mye for matte, jeg har brukt det litt til (0.5) statistikk, faktisk, for det har jo veldig greie verktøy for sånn binomisk og (1.0) eh (0.5) egentlig alle sannsynlighetsfordelingene, men (0.5) har ikke vært like mye geometri helt i det siste. Så jeg føler at jeg kommer til å bruke det litt mer når jeg virkelig begynner innspurten til eksamen, men (1.0) per nå så pugger jeg jo til… til programmeringseksamen som er om to dager. Så… (2.5) ja, eh (3.0) Har ikke vært på (0.5) forelesninger den siste (1.0) uken. Ehm… (3.0) Så det har jo vært mest selvstendig. Har faktisk ikke vært så veldig mye matte de siste ukene i det hele og det store. Eh… (1.0) for jeg har vært opptatt med å pugge til andre eksamener, men det har vært litt innimellom.</td></tr>
<tr><td colspan="2">Context:
Asked if there were any resources that he had used more or less since the previous interview. This is the entirety of his answer.</td></tr>
</table>

Quote location: Adrian 3,4	**Quote categorization**: Unprompted
Translation: I think it is more that… (1.0) that I go from to… (1.0) being in – what to say – the learning phase where I (0.5) learn new things to being in the exam study phase where I just (0.5) challenge myself and like, test in every way, and it is, like… (1.0) two different ways to do things. Now I for instance don't look at… (1.0) I didn't before either, but I do not look at solution suggestions and such (1.0) immediately. So… (2.5) yeah, it is… (1.0) I try to use (0.5) the internet less and (1.0) other (1.0) of that kind of resources, because it is – it is a bit, er… 'cheating' you could say, in the context of exams. Original: Jeg tror vel det er mer… (1.0) at jeg går fra å… (1.0) være i – hva skal jeg si – innlæringsfasen der jeg (0.5) lærer nye ting til å være i eksamenpuggingsfasen der jeg bare (0.5) utfordrer meg selv og liksom tester på alt sett, og det er jo… (1.0) to forskjellige måter å gjøre ting på. Nå ser jeg jo for eksempel ikke på… (1.0) det gjorde jeg ikke før heller, men jeg ser jo ikke på løsningsforslagene og sånn (1.0) med det samme. Så… (2.5) ja, det er jo… (1.0) jeg prøver jo å bruke (0.5) mindre internett og (1.0) andre (1.0) av den typen ressurser, for det er jo – det er jo litt, eh… 'juks' kan en si, i eksamenssammenheng.	
Context: Asked whether anything he mentioned in his answer to the previous question was a lasting change. This is the entirety of his answer.	

Quote location: Adrian 3,9	**Quote categorization**: Unprompted
Translation: What is very nice about it, is that, er … (2.0) well – one can scroll back and forth between previous operations, and it is… (0.5) in that sense there is… there is also quite a lot of memory on this calculator compared to (1.0) the quite simple calculators, for instance that are allowed at [Charlie]. Er, so it – it means that… (0.5) if you were to have a wrong number somewhere in (0.5) your calculation, then you can actually just (0.5) scroll up and as long as you have… (0.5) everything in the right order and use that answer button then… of course it is very easy to just update a whole list of results, and that is very nice, it is… almost like a spreadsheet, without all the bother. Original: Det som er veldig greit med den, det er jo at, eh… (2.0) da – man kan jo bla frem og tilbake gjennom tidligere operasjoner og det er jo… (0.5) sånn sett så er det jo… det er også ganske mye minne på denne kalkulatoren i forhold til (1.0) de helt enkle kalkulatorene, for eksempel tillat på [Charlie]. Eh, så det – det betyr jo at… (0.5) hvis du skulle ha et tall feil et sted oppe i (0.5) utregningen din, så kan du faktisk bare (0.5) bla deg opp og så lenge du har… (0.5) alt i rett rekkefølge og bruker den *answer*-knappen så… er det jo veldig lett å bare oppdatere en hel liste med resultater, og det er jo veldig kjekt, det er jo… nesten litt som et regneark, uten alt bryet.	
Context: Before the interview, Adrian was asked to bring his calculator to show it off and talk about it. At this point, he was asked to describe it and the various features he had mentioned that it had. This is early in his answer, and constitutes about 30% of his answer. He also talks about its functionality for permutations, factorials, tables, and equations of second and third degree. He reiterates that he prefers to solve polynomial equations by hand.	

Quote location: Adrian 3,10	**Quote categorization**: Unprompted
Translation: I think that (2.0) what I would have done, it would be to (0.5) use the first alternative, right wrong, until I arrived at something that was wrong. If it was wrong (1.0) I would have done the exercise again, and if it was still wrong (1.0) I would have (1.0) tried right answer. […] and then I think that if I still had not understood the hint then I would go to the detailed solution. […] if you… just… look in the back of the book first, then of course it – you are the only one you are cheating, and it is… (1.0) shows, of course, on the exams if you have (1.5) if you have just looked at the answer and thought 'yes, that answer looks alright', then (1.0) you have, like, skipped the part where you solve the exercise Original: Jeg tror at (2.0) det jeg ville gjort, det ville være å (0.5) bruke det første alternativet, rett/galt, helt til jeg kom til noe som var galt. Hvis det var galt (1.0) så hadde jeg gjort oppgaven på nytt, og hvis det fortsatt var galt (1.0) så hadde jeg (1.0) prøvd rett svar. […] og da tenker jeg at hvis jeg fremdeles ikke hadde skjønt hintet så hadde jeg gått for den grundige gjennomgangen. […]hvis du… tar og… ser bakerst i boka først, så er jo det – du selv den eneste du jukser for, og det er jo… (1.0) vises jo klart på eksamen hvis du ikke har (1.5) hvis du kun har sett på svaret og tenkt at 'ja, det svaret ser greit ut', så (1.0) har du liksom hoppet litt over den delen der du løser oppgaven	
Context: Asked about the assessment hypothetical. Not included are statements that if he saw that he was wrong due to a minor error, he would not use any other options, and a section where he says he would like a program like the one described in the hypothetical.	

<table>
<tr><td>Quote location:
Adrian 3,15</td><td>Quote categorization:</td></tr>
<tr><td colspan="2">Translation:
I do not like (1.0) to have different (1.0) er, notebooks for different courses. Because then it ends up with – either way with (1.0) ‘oh, shit, did we have math today?’ or ‘oh, no, was that what the physics notebook looked like?’, and then… ends up with hav… – writing math notes in the physics book and physics notes in the statistics book and so on, and so on, so then I rather just bring enough… er, enough notebooks, er… (0.5) with squares or lines that I can write the notes. And then, when I reach a certain milestone where it is no longer… reasonable to have (1.0) all the notes from the previous lectures in… in this (0.5) notebook, then I put it in a folder.

Original:
Jeg liker ikke (1.0) å ha flere forskjellige sånne (1.0) eh, notatbøker til forskjellige fag. Fordi da ender det opp med at – uansett med at (1.0) ‘oh, shit, var det det matte vi hadde i dag’ eller ‘åh, nei, var det sånn fysikkpermen så ut’, og så… ender jeg opp på en må… – å skrive mattenotatene i fysikkboka og fysikknotatene i statstikkboka, også videre og videre, så da har jeg heller bare med meg nok… eh, nok notatbøker, eh… (0.5) med sånn ruter og linjer til at jeg kan skrive notatene. Og så, når jeg kommer til en viss milepæl hvor det ikke lenger er… fornuftig å ha (1.0) alle notatene fra de forrige forelesningene i… i denne (0.5) notatblokka, så tar jeg og setter det inn i en ringperm.</td></tr>
<tr><td colspan="2">Context:
Asked to elaborate after he mentioned a binder during a question about how much work it had been to fill information into the Studert app. This is the first half of his answer. He goes on to describe how convenient his system is.</td></tr>
</table>

From interviews with Amalie

<table>
<tr><td>Quote location:
Amalie 1,2</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
Like, the textbook to (1.5) find… (1.0) like (0.5) the curriculum we are covering and how I am to do the exercises and such. Internet too to find out (0.5) how I solve exercises as well, for inst… - instance for the, and… pretty much like the book. Others in class to cooperate (0.5) on the exercises. Ehm… then I get help from home if I need help on how to solve them, because… (1.5) Er… (0.5) I don’t know, Mom has studied math herself, right, so (0.5) I get a lot of help there, right. And then I learn through doing exercises, that is sitting and doing more exercises and find out what – the stuff I do wrong and (1.0) how I should do them. Also, I look at my old math books. Now that we get, like, exercises that we have had before and such and… how to calculate them. And then the teacher, right.

Original:
Altså læreboka til også (1.5) finne… (1.0) altså (0.5) det stoffet vi har om og hvordan jeg skal regne ut oppgaver og sånn. Internett også til å finne ut (0.5) hvordan jeg løser oppgavene også, for eksem… – eksempler på de og… egentlig ganske likt som boka. Andre i klassen til å samarbeide (0.5) med oppgavene. Ehm… så får jeg hjelp hjemme hvis jeg trenger hjelp til hvordan jeg skal løse de, fordi at… (1.5) Eh… (0.5) I don’t know, Mamma har jo studert matte selv, liksom, så (0.5) jeg får jo en del hjelp der. Også lærer jeg ved å gjøre oppgaveregning, altså sitte og gjøre flere oppgaver og finne ut hva – det jeg gjør feil og (1.0) hvordan jeg skal gjøre de. Også ser jeg i mine gamle mattebøker. Nå når vi får sånn oppgaver som vi har hatt før og sånn og… hvordan jeg skal regne de ut. Også læreren da.</td></tr>
<tr><td colspan="2">Context:
Asked an open question about how she uses resources in the mathematics course. This is the entirety of her answer.</td></tr>
</table>

<table>
<tr><td>Quote location:
Amalie 1,3</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
Ehm… it is mostly while I do exercises and such (2.5) usually. That is usually what math is about, right, exercises. I mostly use the textbook to read the theory of the material.

Original:
Ehm… det er jo mens jeg gjør oppgaver og sånn (2.5) for det meste. Det er jo som regel det matte går ut på da, oppgaver. Læreboka bruker jeg kanskje mest på å lese på teorien på stoffet.</td></tr>
<tr><td colspan="2">Context:
Asked what situations she use the various resources in. This is the entirety of her answer.</td></tr>
</table>

<table>
<tr><td>Quote location:
Amalie 1,4</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
It depend a bit on which exercise – or how the exercise is. If… it is an exercise that I (0.5) recognize and know I have touched on before, then I usually go to the old – my old math books. Er… and if there is something new then I normally use the book, or… work with people from the class (1.0) to find out how (1.0) to calculate it.

Original:
Det kommer litt an på hvilken oppgave – eller hvordan oppgaven er. Hvis… det er en oppgave som jeg (0.5) kjenner igjen og vet jeg har vært inne på før, så ser jeg som regel enten på de gamle – de gamle mattebøkene mine. Eh… og hvis det er noe nytt så bruker jeg som regel boka eller… jobbe sammen med folk i klassen (1.0) for å finne ut av hvordan (1.0) skal regne det ut.</td></tr>
<tr><td colspan="2">Context:
Asked how she decides what resources to use. This is the entirety of her answer.</td></tr>
</table>

Quote location: Amalie 1,5	**Quote categorization**: Semi-prompted
Translation: Well, like right now we have an assignment with… (0.5) Er… (0.5) which has points in a plane and such and then I know – I had that when I ha… – attended secondary, so then I go back to look at the (0.5) exercises I did there (1.0) er… in addition to working with people in class to figure out how we should (1.0) calculate it. Original: Altså sånn som nå har vi jo en innlevering med… (0.5) Eh… (0.5) som er punkter i plan og sånn og da vet jeg – det hadde jeg jo når jeg ha… – gikk på videregående, så da går jeg tilbake og ser på de (0.5) oppgavene jeg gjorde der (1.0) eh… i tillegg til da at jeg jobber sammen med folk i klassen for å finne ut hvordan vi skal (1.0) regne det ut.	
Context: Asked to elaborate on her answer to the previous question through an example.	

Quote location: Amalie 1,8	**Quote categorization**: Unprompted
Translation: Well, when I do exercises then (0.5) I look at (0.5) how I have calculated it before, then I find that – like, I need to like, *refresha* (0.5) my memory on how I (1.0) solve it. However, it is much easier to then (0.5) get back into how I solve the exercises when I see how I have done it before, because then it is myself that has done it and not just, like, something I read in the book. I think it is easier to learn if I do many exercises, than if I just sit and read a lot of theory. Original: Ja, altså når jeg regner oppgaver så (0.5) ser jeg jo på (0.5) hvordan jeg har regnet de før, så finner jeg jo ut av – altså, jeg må jo liksom *refresha* (0.5) minnet om hvordan jeg (1.0) løser det igjen. Men det er ganske mye lettere å så da (0.5) komme inn i hvordan jeg skal løse oppgavene når jeg ser på hvordan jeg har gjort det før for da er det jeg selv som har gjort det og ikke liksom bare noe jeg leser i boka. Synes det er lettere å lære hvis jeg regner mye oppgaver, enn hvis jeg bare sitter og leser teori.	
Context: Answered to the previous question that her old math books was a resource she felt like she had made her own. Was asked to elaborate on how she used them. This is the entirety of her answer. The use of the word *refresha* was a result of her adding Norwegian grammar to the word refresh.	

<table>
<tr><td>Quote location:
Amalie 1,10</td><td>Quote categorization:
Semi-prompted</td></tr>
<tr><td colspan="2">Translation:
I guess I use working with others because it is what I like the best, but it is often that I use (0.5) what I have done before as well. So (1.0) it might work two ways, that (1.0) what I have done before I sort of learn from, and when working with others we rather discuss the exercises.

Original:
Jeg bruker vel kanskje det å jobbe mest med andre fordi at det er det jeg liker best, men det er jo veldig ofte jeg bruker (0.5) det jeg har gjort før også. Så (1.0) det går kanskje på begge deler, at (1.0) det jeg har gjort før det lærer jeg på en måte av, og det å jobbe med andre, da diskuterer vi heller rundt oppgaven.</td></tr>
<tr><td colspan="2">Context:
Asked whether how much she liked a resource influenced how much she used it. This is the entirety of her answer.</td></tr>
</table>

<table>
<tr><td>Quote location:
Amalie 1,12</td><td>Quote categorization:
Semi-prompted</td></tr>
<tr><td colspan="2">Translation:
Well, if there are new topics, I usually use the textbook to read up on the material and (1.0) figure out what to do and such. While if there are old topics – or topics that we have had then (1.0) I look at what I have done, right.

Original:
Nei, hvis det er nye temaer så bruker jeg som regel læreboka til å lese meg opp på stoffet og (1.0) finne ut av hvordan jeg skal gjøre det og sånne ting. Mens hvis det da er gamle temaer – eller temaer som vi har hatt så (1.0) ser jeg jo på det som jeg har gjort.</td></tr>
<tr><td colspan="2">Context:
Asked to elaborate after she answered in the affirmative that her use of resources varied from topic to topic. This is the entirety of her answer.</td></tr>
</table>

<table>
<tr><td>Quote location:
Amalie 1,16</td><td>Quote categorization:
Semi-prompted</td></tr>
<tr><td colspan="2">Translation:
I work more with others than what I do alone, but I feel like I learn better then.

Original:
Jeg jobber nok mer sammen med andre enn hva jeg jobber alene, men jeg føler jeg lærer mye mer da.</td></tr>
<tr><td colspan="2">Context:
Asked how much she worked with others compared to alone. This is the entirety of her answer.</td></tr>
</table>

<table>
<tr><td>Quote location:
Amalie 1,20</td><td>Quote categorization:
Semi-prompted</td></tr>
<tr><td colspan="2">Translation:
It is like – or first and foremost if I get an exercise (0.5) er… (1.0) say, if I got something like what we had an assignment on, which was to find out – out if (0.5) er, the points were in the same plane. And… (0.5) then I would – If I had not known how I should do it, then I would, for instance, ask ‘okey, how – what am I to do to find out whether they are in the same plane?’ And then she would explain to me that I first need to find the vector and then the normal vector to find the equation in the plane. And then I would test myself on how I did it and put in (0.5) those things, and then she would (1.5) have seen if it was (0.5) correct or if I – what I had to change and such.

Original:
Det er jo liksom – eller først og fremst hvis jeg får en oppgave (0.5) eh… (1.0) si hvis jeg skulle fått sånn som den som vi hadde på innlevering nå, den var å finne om – ut om (0.5) eh, punktene lå i samme plan. Og… (0.5) da ville jeg – hvis jeg ikke hadde visst hvordan jeg skulle gjort det, så ville jeg for eksempel spurt ‘okey, hvordan – hva er det jeg skal gjøre for å finne ut om de ligger i samme plan?’ Og da ville jo hun forklart meg det at jeg og må først finne vektoren og så normalvektoren for å finne likningen til planet. Og så ville jeg ha testet selv hvordan jeg gjorde det også puttet inn (0.5) de tingene, og så ville hun (1.5) sett om det var (0.5) rett eller om jeg – hva jeg måtte forandre på og sånn.</td></tr>
<tr><td colspan="2">Context:
Asked whether discussion with her mother was specific to the exercise at hand or more general.</td></tr>
</table>

Quote location: Amalie 3,1	**Quote categorization**: Semi-prompted
Translation: No, using the same ways to learn things that, really (1.0) that I have always done. Original: Nei, bruker de samme måtene å lære meg ting på, egentlig (1.0) som jeg alltid har gjort.	
Context: Asked if there had been any changes to how she used resources since the first interview. This is the entirety of her answer.	

From interviews with Andreas

Quote location: Andreas 1,2	**Quote categorization**: Unprompted
Translation: I usually go to… (2.0) the teacher if I am stuck. If fellow students cannot help, er… (2.5). Usually I get a very detailed (1.0) calculation, very detailed *fremgangsmåte** and explained very well. Er… (5.0) er… (0.5) digital resources such as Wolfram Alpha, for instance, er… (0.5) can also give me that option, that calculation possibility (0.5) if I am stuck. It can also show visual representation, if I… (0.5) for instance am not sure about whether I can show – show something on the calculator. Original: Jeg går som regel til… (2.0) læreren hvis jeg står fast. Om ikke medelevene kan hjelpe, eh… (2.5). Som regel så får jeg veldig detaljert (1.0) utregning, veldig detaljert fremgangsmåte og forklarer det veldig bra. Eh… (5.0) Eh… (0.5) Digitale hjelpemiddel sånn som for eksempel Wolfram Alpha, eh… (0.5) kan også gi meg den muligheten, den utregningsmuligheten (0.5) om jeg står fast. Den kan også vise grafisk fremstilling, om jeg… (0.5) for eksempel er usikker på det jeg klarer å vise – vise frem på kalkulator.	
Context: Asked how he used the various resources he mentioned in his answer to the previous question. This is the entirety of his answer. **Fremgangsmåte* may refer either to a solution method or to a more general approach to a task.	

Quote location: Andreas 1,4	**Quote categorization**: Unprompted
Translation: Yes. Er… (3.5) for instance, assignments make it so we (0.5) as a class (0.5) er… usually sit with people we do not sit with usually, to try to work and (1.5) get through the assignments as well as possible. Original: Ja. Eh… (3.5) For eksempel innleveringer gjør at vi (0.5) som en klasse (0.5) eh… som regel sitter sammen med de vi vanligvis ikke pleier sitter sammen med, for å prøve å jobbe og (1.5) komme oss igjennom innleveringer på en best mulig måte.	
Context: Asked whether different situations caused him to use resources differently. This is at the start of his answer. He also mentions working more alone or in smaller groups normally.	

Quote location: Andreas 1,7	**Quote categorization**: Unprompted
Translation: It was a fellow student who recommended it to me. Er, he (0.5) used it when we sat in… a group. Er, I asked what it was and he explained. (3.0) And… yeah. Since then I have, well… (1.5) well, had use for it. Original: Det var en medelev som anbefalte meg. Eh, han (0.5) brukte det når vi satt i… gruppe. Eh, jeg spurte hva det var, og han forklarte. (3.0) Og… ja. Siden det så har jeg vel… (1.5) ja, nytte av det.	
Context: Asked how he came across Wolfram Alpha. This is the entirety of his answer.	

<table>
<tr><td>Quote location:
Andreas 1,9</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
I like the most to work in a (0.5) active and (1.5) well (0.5) coope… – cooperatively minded group, people who like to talk, people who like to (1.5) shoot ideas. Er… That is probably the environment I enjoy the most. Ehm… (0.5) I dislike the most to (1.5) have to learn (0.5) the curriculum by myself, for instance if a lecturer says that you are to read these pages in the book, understand the curriculum (1.0) then… potentially do exercises afterwards. That is a situation I… (2.0) dislike.

Original:
Jeg liker best å jobbe i en (0.5) aktiv og (1.5) ja (0.5) samar… – samarbeidsvillig gruppe, folk som liker å snakke, folk som liker å (1.5) skyte ideer. Eh… Det er nok det miljøet jeg trives best i. Ehm… (0.5) Jeg misliker mest å (1.5) måtte lære (0.5) stoffet selv, for eksempel om en foreleser sier at du skal lese disse sidene i boka, forstå stoffet (1.0) så… eventuelt gjøre oppgaver i etterkant. Det er situasjoner jeg… (2.0) misliker.</td></tr>
<tr><td colspan="2">Context:
Asked if there were any resources that he liked particularly well or disliked. This is the entirety of his answer.</td></tr>
</table>

<table>
<tr><td>Quote location:
Andreas 1,14</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
Usually we are… three to four people. I try to avoid that it becomes too many, as it (0.5) becomes too much noise and distractions.

Original:
Som regel så er vi… tre eller fire stykker. Jeg prøver å unngå at det blir for mange, da det (0.5) blir for mye støy og mye distraksjoner.</td></tr>
<tr><td colspan="2">Context:
Asked how many fellow students he usually works with when he works with others. This is the entirety of his answer.</td></tr>
</table>

Quote location: Andreas 2,1	**Quote categorization**: Prompted
Translation: I: Ehm, you said you go to all the lectures you are able to, ehm, use pen and paper to learn formulas and notation. If you need visual representation, you go to GeoGebra, Wolfram Alpha or calculator. For pure calculation, you mostly use old notes. You ask questions to teacher and fellow students if you are stuck on something, and you have not done that many recommended exercises. A3: Correct. Original: I: Ehm, denne gangen så har jeg skrevet ned litt – prøvd å oppsummere det du sa sist, og lurte på om du kunne si om det er noe du vil legge til, rette på eller (0.5) noe som eventuelt har endret seg siden. Ehm, du sa at du går i alle forelesningene du har mulighet til, ehm, bruker penn og papir for blant annet å lære formler og skrivemåter. Om du har behov for grafisk representasjon så bruker du geogebra, Wolfram Alpha eller kalkulator. Ved ren regning bruker du mer gamle notatet. Du stiller spørsmål til lærer og medelever om du står fast på noe, og du har ikke gjort så mye av de anbefalte oppgavene. A3: Korrekt.	
Context: Preceded by an explanation that the interviewer is attempting to summarize Andreas’ statements from the first interview. Later, when asked specifically about resources used more or less, he said he used the streaming more. He also said that he used digital resources less and what he had learned in the lectures more.	

Quote location: Andreas 2,7	**Quote categorization**: Unprompted
Translation: I: I see. (3.5) Ehm (1.5) last time you said when it comes to resources that you have made your own then (0.5) primarily that when you explain to other students you use a lot of metaphors and practical examples. Do you have more to add now? A3: (7.0) No, I stand by that it – I do it the same way, I do. Original: I: Ja. (3.5) Ehm (1.5) sist så sa du når det gjelder ressurser du har gjort dine egne så (0.5) først og fremst når du skal lære bort til andre elever at du bruker mye metaforer og praktiske eksempler. Har du mer du vil legge til nå? A3: (7.0) Nei, det står jeg egentlig fast på, at det – jeg gjør det på samme måten, jeg gjør det.	
Context: It was established at the start of the interview that the interviewer gave various summaries of Andreas' answers from the previous interview.	

Quote location: Andreas 2,9	**Quote categorization**: Semi-prompted

Translation:
I: Okey. Ehm… (1.0) You also said that you try to find at least one person to do exercises with, that you (0.5) do not like to learn things on your own. Ehm… often work with 2-3 others, and (1.0) er (0.5) there have not been much group work this year, but I did not catch if you meant group work organized by…
A3: No, it is – then I mean (1.5) that we on our own find groups, that we find either friends or classmates to work with.
I: I see. How does that fit, like, as of now?
A3: It still fits as of now, it is… (0.5) hard to find the time, and it is hard to find (0.5) others who have found time exactly when I have found time for mathematics. So if I work on exercises, I probably work alone.

Original:
I: Okey. Ehm… (1.0) Du sa også at du prøver å finne minst en person å gjøre oppgaver med, at du (0.5) liker ikke å skulle lære ting alene. Ehm… jobber gjerne samen med 2-3 andre, og (1.0) eh (0.5) det har vært lite gruppearbeid i år, men jeg fikk ikke med meg om du mente organisert gruppearbeid av…
Andreas: Nei, det er – da mener jeg (1.5) at vi selv finner grupper, at vi selv finner enten venner eller klassekammerater å jobbe med.
I: Ja. Hvordan stemmer det, sånn, per nå?
Andreas: Det stemmer fortsatt per nå, det er… (0.5) vanskelig å sette av tid, og det er vanskelig å finne (0.5) andre som har satt av tid akkurat når jeg har satt av tid til matematikk. Så blir det å jobbe med oppgaver, så blir det nok å jobbe alene.

Context:
It was established at the start of the interview that the interviewer gave various summaries of Andreas' answers from the previous interview.

<table>
<tr><td>Quote location:
Andreas 2,11</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
Notes are put up. Er… I try to avoid (0.5) using those notes. Er… I guess I have not used those notes at all. Instead I attend the lectures and then I see through the lecture and write down notes. I try to note everything that the teacher presents on the blackboard.

Original:
Notater blir lagt ut. Eh… jeg prøver å unngå å (0.5) å bruke de notatene. Eh… jeg har vel faktisk ikke brukt notatene i det hele tatt. Jeg går heller på forelesninger og så ser jeg gjennom forelesninger og så skriver ned egne notater. Jeg prøver å notere alt læreren tar frem på tavla.</td></tr>
<tr><td colspan="2">Context:
Asked whether any resources are provided through the course’s web pages, and if so, whether he used them. This is the entirety of his answer.</td></tr>
</table>

<table>
<tr><td>Quote location:
Andreas 3,4</td><td>Quote categorization:
Semi-prompted</td></tr>
<tr><td colspan="2">Translation:
Yes, and then there is that mental bar, it is easier to ask students than to go to the teachers. Every time it… (1.5) you run into a hurdle.

Original:
Ja, også er det vel den terskelen, det er lettere å spørre elever enn det er å gå til lærerene. Hver gang det… (1.5) du møter kvist.</td></tr>
<tr><td colspan="2">Context:
To the previous question, said that he had not prioritized mathematics lately and that he recently relied on students who had learned more than him. Was asked whether he did so because it was a more efficient way to learn. This is the entirety of his answer.</td></tr>
</table>

Quote location: Andreas 3,6	**Quote categorization**: Unprompted

Translation:
Yes. (4.5) I have chosen to put a lot of emphasis on the streaming, rather than attending lectures because of… (1.5) the quality of what I see of (1.0) the… (0.5) physical quality – it is easier to look at a computer screen rather than to have… a camera pick it up and then project it onto the canvas. So it is much easier to get it shown – straight onto a computer screen. Easier to see details, and then I can control the pace to my preference, if there is something I am unsure about then I can stop it completely. Potentially if there is something I have (0.5) an understanding for or under control, then I can (0.5) increase the speed of the (0.5) playback. And I think it is an, er… efficient way, for me, to learn.

Original:
Ja. (4.5) Jeg har valgt å legge stor vekt på *streamingen*, fremfor å møte til forelesningen på grunn av at… (1.5) kvaliteten på det jeg ser av (1.0) den… (0.5) fysiske kvaliteten – det er lettere å se på dataskjermen i stedet for å ha… et kamera plukke det opp og så blir prosjektert opp på et lerret. Så det er mye lettere å få det vist på – rett på en dataskjerm. Lettere å se detaljer, og så kan jeg da styre tempoet til min grad, hvis det er noe jeg er usikker på så kan jeg stoppe det helt. Eventuelt om det er ting som jeg har (0.5) forståelse for eller kontroll på, så kan jeg da (0.5) øke hastigheten på (0.5) tilbakespillingen. Og jeg synes det er en, eh… effektiv måte, for min del, å lære på.

Context:
Asked to talk about the streaming of the lectures and how he had used it. This is the entirety of his answer.

<table>
<tr><td>Quote location:
Andreas 3,7</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
I have – I want to control what I do, that the work I do is correct and that (1.0) I do not learn mistakes (1.0) or adopt poor habits. Er (0.5) so if I have the option to evaluate myself, I will.

Original:
Jeg har – jeg har lyst til å kontrollere det jeg gjør, at arbeidet jeg gjør er rett og at (1.0) jeg ikke lærer feil (1.0) eller legger meg til dårlige rutiner. Eh (0.5) så har jeg muligheten til å kontrollere meg, så gjør jeg det.</td></tr>
<tr><td colspan="2">Context:
Asked how much he uses the answers to exercises in the textbook. This is the first half of his answers. He goes on to talk about the importance of being able to move on and not spend too much time on an exercise that one is stuck on.</td></tr>
</table>

Quote location: Andreas 3,8	**Quote categorization**: Unprompted

Translation:
I had probably liked to see (0.5) all four (1.0) methods be (0.5) used, I would probably want to lea… – get experience using all four options. (2.0) Both because (0.5) when you get a detailed solution then… you know precisely (1.0) what is done, potentially what you did wrong, potentially what you did right, while if you get, for instance just a right or… wrong answer (1.0) then you feel that insecurity while you do the exercise and you… you cannot (0.5) control it, you just know that either you have done it right, or you have done it wrong. Er, and that is how exams eventually will be. Potentially if you sit with (1.5) questions or exercises that no one else has the answer to. (2.0) Then you do not have that … (1.5) well, benefit that you can always control what you do. (2.5) So I think I… (1.0) given those four, implementing all four can be (2.0) be a good solution, and possibly (1.5) limited. That on certain exercises there is just the one option. Potentially (1.5) er, start somewhere and then give more and more access. You start by first getting to know if it is right or wrong, and then (1.0) you increase – you can ask for a hint, and then you can ask for an answer, then you can ask for detailed, for instance.

Original:
Jeg hadde nok likt å sett (0.5) alle fire (1.0) metodene blitt (0.5) brukt, jeg hadde nok ønsket å ha læ… – fått erfaringer med å bruke alle fire metodene. (2.0) Både fordi at (0.5) når du får det i en detaljert gjennomgang så… vet du nøyaktig (1.0) hva som blir gjort, eventuelt hva du gjorde feil, eventuelt hva du gjorde rett, mens hvis du får for eksempel bare et rett eller… galt svar (1.0) så kjenner du litt på den usikkerheten mens du gjør oppgaven og du… du klarer ikke å (0.5) kontrollere det, du vet bare enten så har du gjort det rett, eller så har du gjort det feil. Eh, og det er nå sånn en eventuell eksamen blir. Eventuelt om du sitter med (1.5) spørsmål eller oppgaver som ingen andre kan svaret på. (2.0) Da har ikke du den… (1.5) ja, goden at du alltid kan kontrollere det du gjør. (2.5) Så jeg tror jeg… (1.0) ut ifra de fire, at å implementere alle fire kan være (2.0) være en god løsning, og gjerne med (1.5) tvang. At i enkelte oppgaver så er det bare den muligheten. Eventuelt (1.5) eh, starte på et sted og så gi de mer og mer tilgang. Du starter med først får du bare vite om det er rett eller galt, og så (1.0) øker du da – du kan spørre om da et hint, og så kan du spørre om svar, så kan du spørre om detaljert, for eksempel.

Context:
Asked about the assessment hypothetical. This is the entirety of his answer.

From interviews with Anna

<table>
<tr><td>Quote location:
Anna 1,1</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
Er… I… (1.0) attend the lectures and all that and then I use the notes there to (0.5) er, refresh and go through the most important. And then I use the math book to – or the textbook, to (0.5) do exercises and look at (1.0) different ways to solve exercises that are different from the lectures. And then calculator and (0.5) pencil and paper and such. And then I work a lot with students and (1.5) co-operate with them.

Original:
Eh… Jeg… (1.0) er med på forelesningene, og alt det der og så bruker jeg notatene der til å (0.5) eh, repetere og gå gjennom det viktigste. Og så bruker jeg mattebok til å – eller tekstboka, til å (0.5) gjøre oppgaver og se på (1.0) forskjellige måter å løse oppgavene som er forskjellig fra forelesningene. Og så kalkulator og (0.5) blyant og papir og sånn. Og så jobber jeg mye med elever og (1.5) samarbeider med dem.</td></tr>
<tr><td colspan="2">Context:
Asked an open question about how she used resources for mathematics. This is the entirety of her answer.</td></tr>
</table>

<table>
<tr><td>Quote location:
Anna 1,3</td><td>Quote categorization:
Semi-prompted</td></tr>
<tr><td colspan="2">Translation:
Yes. Er… (1.5) if (1.0) there is something I do not quite understand, even though I have… through the notes and the book, it might happen that I (0.5) search online for an explanation, right. And such.

Original:
Ja. Eh… (1.5) hvis (1.0) det er noe som jeg ikke helt forstår, selv om jeg har… gjennom notatene og i boka, så kan det hende at jeg (0.5) søker på nettet om en annen forklaring, da. Og sånn.</td></tr>
<tr><td colspan="2">Context:
Asked whether she use resources differently in different situations.</td></tr>
</table>

<table>
<tr><td>Quote location:
Anna 1,10</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
I guess I use (1.0) all of them anyways, when I… Er… Like with (1.5) GeoGebra and all of that – I do not use it as much as maybe I should, but…

Original:
Jeg bruker nå (1.0) alle uansett, når jeg… Eh… Sånn som (1.5) geogebra og alt det der så – jeg bruker ikke det så mye som jeg kanskje burde, men…</td></tr>
<tr><td colspan="2">Context:
Asked what resources she liked to use. This is the entirety of her answer.</td></tr>
</table>

<table>
<tr><td>Quote location:
Anna 1,17</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
I read through the chapters that we have been through in the lectures. And then I do exercises (1.5) And… the answers to the exercises I just use to check if I got the right answer, or if (1.0) if I do not get it and I just sit by myself… then I look at it.

Original:
så (0.5) leser jeg gjennom kapitlene som vi har vært gjennom i forelesningene. Og så gjør jeg oppgavene (1.5) og… løsningsforslaget til oppgavene bruker jeg bare til å sjekke om jeg har fått rett svar, eller om (1.0) hvis jeg ikke får det til og jeg sitter bare for meg… så ser jeg i den.</td></tr>
<tr><td colspan="2">Context:
Asked to describe her mind map. This is approximately the middle of her answer. Before it, she talks about attending lectures, taking notes and using her notes for repetition. Afterwards, she talk about discussion with fellow students to check her answers.</td></tr>
</table>

Quote location: Anna 2,1	**Quote categorization**: Prompted
Translation: I: So, this time I… (0.5) have tried to make summaries of things you said last time, so (0.5) part of the interview is to (1.0) say if there is something you want to correct, add or something that has changed since last time. So (0.5) I have written that (2.0) you take notes during lectures and afterwards og through the notes and mark what is important. That you refresh often, both when you work on exercises and often during the weekends. That you t… – in – that you also use the textbook, calculator, writing equipment, working with others on exercises and potentially search online for explanations. Of digital resources you have so far only used calculator, but you also have GeoGebra available. So (0.5) is there anything you want to correct or add to (0.5) that? A4: No, it sounds good [laughs]. Original: I: Så, denne gangen så… (0.5) har jeg prøvd å lage oppsummeringer av ting du sa sist, så (0.5) deler av intervjuet er å (1.0) si om det er noe du vil rette på, legge til og om det er noe som har endret seg siden den gang da. Så (0.5) jeg har skrevet at (2.0) du tar notater på forelesning og etterpå går gjennom notatene og markerer det som er viktig. At du repeterer ofte, både når du jobber med oppgaver og ofte i helgene. At du p… – i – at du også bruker tekstbok, kalkulator, skrivesaker, jobbe med andre om oppgaver og eventuelt søke på internett for å finne forklaringer. Av digitale ressurser har du foreløpig bare brukt kalkulator, men du har også tilgjengelig geogebra. Så (0.5) er det noe du vil rette på eller legge til (0.5) der? Anna: Nei, det høres greit ut [ler].	
Context: The start of the second interview.	

<table>
<tr><td>Quote location:
Anna 2,2</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
Er… I work more with others, maybe.

Original:
Eh… jeg jobber mer med andre, kanskje.</td></tr>
<tr><td colspan="2">Context:
Asked whether there were any changes to how she used resources since the previous interview. When asked the reason for the change she mentioned, said that it had to do with who was available and more were interested in forking together because the curriculum had become more difficult.</td></tr>
</table>

<table>
<tr><td>Quote location:
Anna 2,4</td><td>Quote categorization:
Prompted</td></tr>
<tr><td colspan="2">Translation:
I: Ehm (2.0) Then I wrote from last time that (2.0) there were no resources you felt you had made your own, has that (0.5) changed at all (1.0) since then?
A4: No. [laughs]

Original:
I: Ehm (2.0) Så skrev jeg fra sist at (2.0) det ikke var noen ressurser du følte du hadde gjort til dine egne, har det (0.5) endret seg noe (1.0) siden da?
Anna: Nei. [ler]</td></tr>
<tr><td colspan="2">Context:
It was established at the start of the interview that the interviewer gave various summaries of Anna’s answers from the previous interview.</td></tr>
</table>

<table>
<tr><td>Quote location:
Anna 2,5</td><td>Quote categorization:
Prompted</td></tr>
<tr><td colspan="2">Translation:
I: Ehm… I see, so speaking of, working with others, last time you said that you (1.0) often work with – that you worked with two to three (0.5) fellow students when you worked with someone and that it was often one to two times a week that you worked with others. So (1.5) You said it had gone up a bit, what – how much do you work with others now?
A4: Er… (2.5) three to four times, maybe.

Original:
I: Ehm… Ja, sånn apropos, jobbe med andre så sa du sist at du (1.0) ofte jobbet med – at du jobbet med 2-3 (0.5) medelever når du først jobbet med noen og at det stort sett var en til to ganger i uka at du jobbet med andre. Så (1.5) Du sa det hadde økt litt, hva – hvor mye vil du si du jobber med andre nå?
Anna: Eh… (2.5) 3-4 ganger kanskje.</td></tr>
<tr><td colspan="2">Context:
It was established at the start of the interview that the interviewer gave various summaries of Anna’s answers from the previous interview.</td></tr>
</table>

<table>
<tr><td>Quote location:
Anna 3,2</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
Yeah. [laughs] Er… (3.0) No… (0.5) lectures are over, right. So (0.5) has more time to (0.5) work and then I have not worked as much on math lately, because I have had other exams and other things to do than… (1.0) well, now I have started on it again.

Original:
Ja. [ler] Eh… (3.0) Nei… (0.5) forelesningene er over da. Så (0.5) har mer tid til å (0.5) jobbe og så har jeg ikke jobbet like mye med matte i det siste, for jeg har hatt andre eksamener og andre ting å gjøre enn… (1.0) ja, nå har jeg begynt på igjen nå da.</td></tr>
<tr><td colspan="2">Context:
Asked if there had been any changes to how she used resources since the previous interview. This is the entirety of her answer.</td></tr>
</table>

<table>
<tr><td>Quote location:
Anna 3,6</td><td>Quote categorization:
Semi-prompted</td></tr>
<tr><td colspan="2">Translation:
Er, will try to get better overview of what it says in it and such, so I will try to use it more (0.5) throughout the year.

Original:
Eh, skal prøve å ha litt mer oversikt over hva som står i den og sånn, så jeg prøver å bruke den litt mer (0.5) gjennom hele året.</td></tr>
<tr><td colspan="2">Context:
After saying she would use the formula collection more in the new course, was asked whether she meant throughout the year or just for the exam period. This is the entirety of her answer.</td></tr>
</table>

<table>
<tr><td>Quote location:
Anna 3,8</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
I have gone through the lectures, from the notes, and then I compare with what it says in the formula collection so I do not get anything redundant.

Original:
har gått gjennom fra forelesning, fra notatene, og så har jeg sammenliknet med det som står i formelsamlingen sånn at det ikke står dobbelt opp.</td></tr>
<tr><td colspan="2">Context:
Asked to elaborate after saying that the exam sheet was a resource that she felt like she had made her own. This is the entirety of her answer.</td></tr>
</table>

<table>
<tr><td>Quote location:
Anna 3,12</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
After the lectures I go through and mark what I… (0.5) consider important, and then I also see it when I do exercises, what is important.

Original:
etter forelesningene så går jeg gjennom og markerer det jeg… (0.5) mener er viktig, og så ser jeg det også når jeg gjør oppgaver, hva som blir viktig.</td></tr>
<tr><td colspan="2">Context:
Asked how she decides what she considers important when she takes notes, after mentioning previously that she noted down what was important when she attended lectures. This is the entirety of her answer.</td></tr>
</table>

From interviews with Benjamin

<table>
<tr><td>Quote location:
Benjamin 1,3</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
Kind of depends on how much time I have, for instance. Ehm, if I have good time, then… I sit down with the videos, and og through them, like, thoroughly. Ehm… (1.5) If not, I just have to (1.0) read in the textbook, and then (0.5) attend the lectures that have been scheduled. (2.0) Er, if I have a lot of time, then… I try to go through (2.0) prior to lectures, for instance. (7.0) [tired groan] I mostly think about how much time I have, but ehm… (4.0) Well, so… (3.5) Er, the videos are the simplest. And to – to get an explanation to things, to – to get it shown how to do it. That is preferable.

Original:
Kommer litt an på hvor mye tid jeg har, for eksempel. Ehm, hvis jeg har god tid, så… setter jeg meg gjerne ned med videoene, og går liksom nøye gjennom. Ehm… (1.5) Hvis ikke, så må jeg bare (1.0) lese i boka, og så (0.5) komme på de forelesningene som er satt opp. (2.0) Eh, hvis jeg har god tid, så… prøver jeg å gå gjennom (2.0) før forelesning for eksempel. (7.0) [trøtt stønn] Jeg tenker først og fremst på jo mye tid jeg har, men ehm… (4.0) Ja, så… (3.5) Eh, det er mest lettvint med de videoene. Og for å – for å få en forklaring på ting, for å – for å få vist litt hvordan det skal gjøres. Det er jo å foretrekke.</td></tr>
<tr><td colspan="2">Context:
Asked how he decided what resources to use. This is the entirety of his answer.</td></tr>
</table>

<table>
<tr><td>Quote location:
Benjamin 1,5</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
Has to be the video things, then (2.0) Er… (2.5) Like, er… (2.0) uses them to… (2.0) er… (1.0) well, skip to where I want to… see from, for instance, if I want a (0.5) calculation that I take (2.0) Faster than… what is in the video, then I just skip past it, and if there are things I need multiple times, then like (0.5) I see it several times and take notes during it and… (1.5) then (0.5) repeat er… (2.0) exactly that small part of the video again and again, and then I might skip past the rest.

Original:
Må være de videogreiene, da (2.0) Eh… (2.5) Liksom, eh… (2.0) bruker de til å… (2.0) eh… (1.0) Ja, spole til der jeg ønsker å… se fra for eksempel, hvis jeg ønsker en (0.5) utledning som jeg tar (2.0) Fortere enn… det som er utledet i video så hopper jeg jo bare over det, og hvis det er en ting jeg må ha flere ganger, så liksom (0.5) Ser på det flere ganger og noterer samtidig og… (1.5) så (0.5) gjentar eh… (2.0) akkurat den lille delen av videoen igjen og igjen, og så kan det hende jeg hopper over resten.</td></tr>
<tr><td colspan="2">Context:
Asked if there were any resources that he felt like he had made his own. This is the entirety of his answer.</td></tr>
</table>

<table>
<tr><td>Quote location:
Benjamin 1,6</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
M… (6.0) That is a bit of a hard question, but ehm… For my part I think I (1.5) If I get a good explanation, I think most things are easy. Er… (3.0) That is just in my case, right, from experience it is not as (1.0) Everyone else do not always take it as quickly, but er… (3.0) Er, it is just about having a bit of a base for, er… what is underneath, and then… get an explanation for (1.5) how it is derived, and then I think most things are alright

Original:
M… (6.0) Det er nok litt vanskelig spørsmål, men ehm… For min del så syns jeg (1.5) Hvis jeg får en god forklaring så synes jeg det meste er lett. Eh… (3.0) Det er bare for min del da, erfaringsmessig så er ikke det like (1.0) Ikke alltid alle andre følger det like fort, men eh… (3.0) Eh, det handler bare om å ha litt sånn grunn for, eh… hva som ligger under, og så… få en forklaring på (1.5) hvordan det skal utledes, og så syns jeg det meste er veldig greit</td></tr>
<tr><td colspan="2">Context:
Asked why he found some things easier. Also mentions formulas as something he may not remember.</td></tr>
</table>

<table>
<tr><td>Quote location:
Benjamin 1,12</td><td>Quote categorization:
Semi-prompted</td></tr>
<tr><td colspan="2">Translation:
Yes… When I work alone, then… (1.5) there are those videos, for instance, right, when I work with others it is mostly ehm... (2.0) do the exercises, for instance we are to do and then it is just to… do them and then potentially look at formulas and look at… like, small elaborations in books, ore online or [inaudible] where one can find examples of how (0.5) those exact problems are solved, for instance.

Original:
Ja… Når jeg jobber alene så… (1.5) er det disse videoene for eksempel da, når jeg jobber med andre så er det mest ehm... (2.0) gjøre de oppgavene, for eksempel vi skal gjøre og da er det bare å… gjøre de og så eventuelt se på formler og se på… sånn, små utledninger i bøker, eller på nett eller [uforståelig] hvor man finner eksempler på hvordan (0.5) akkurat de problemene skal løses for eksempel.</td></tr>
<tr><td colspan="2">Context:
Asked if there are any differences between how he used resources when he worked with others and when he worked alone. This is the entirety of his answer.</td></tr>
</table>

<table>
<tr><td>Quote location:
Benjamin 2,1</td><td>Quote categorization:
Prompted</td></tr>
<tr><td colspan="2">Translation:
I: So, (1.0) this time I have tried to make some summaries of what you said last time, and then (1.0) I would like you to say if there is something that (0.5) you would add, either (0.5) ehm (0.5) because it is new or because it (1.0) to improve the summary, right. So (1.0) er, since last time, I got that you (1.0) use the video lectures, textbook as a supplement and MyMathLabs for exercises. That when you have a lot of time you prepare before lectures. Use video… – that – use the video lectures quite a bit, and… with less time you use the textbook and lectures. And on occassion you use Wolfram Alpha, google things and use youTube videos.
B1: Yes.

Original:
I: Så, (1.0) denne gangen så har jeg prøvd å lage litt oppsummering av det du sa sist, og så (1.0) vil jeg at du skal si om det er noe som (0.5) du vil legge til enten (0.5) ehm (0.5) fordi det er nytt eller fordi det (1.0) for å forbedre oppsummeringen da. Så (1.0) eh, sist så fikk jeg med meg at du (1.0) bruker videoforelesningene, tekstbok som supplement og mymathlabs for oppgaver. At når du har god tid så forbereder du deg før forelesning. Bruker video… – at – bruker videoforelesninger en god del, og… ved dårligere tid bruker mer tekstbok og forelesninger. Og det hender du bruker Wolfram Alpha, googler ting og bruker youtube-videoer.
B1: Ja.</td></tr>
<tr><td colspan="2">Context:
The start of the second interview.</td></tr>
</table>

Quote location: Benjamin 2,3	**Quote categorization**: Unprompted

Translation:
Er… lately… (2.0) I have used textbook a lot, er… (2.0) personally. There have been many other courses that I have had – had to work on as well, so I have made math a rather low priority. Ehm (1.5) which have lead to me not having time to watch videos or familiarize myself with it as well as I really want to. Ehm, so it will be (1.0) read… in the textbook to understand, like, the basic principles and then be in the lectures Ehm… (1.5) Er… because I – personally I… grasp it quite well. After – if I (1.0) if I get the idea, that is where things come from, and such, like if it is shown in the book or a lecture, then I feel like I grasp it, personally. So it is… (1.0) as long as it is understandable where… things come from, how (1.0) things are put there and there, then I usually grasp it quite well (1.0) just by reading the textbook. Er, really not – then I do not need to do that many exercises, to – at least not to understand it, right. To become good at it, of course I have to do a bit more exercises, but… (2.0) Until now it has really just been to get – like, to keep pace on the understanding parts, at least, then in the exam period I can pick up with more exercises, so… A lot with textbook at the moment, not that much else, so… (0.5) just up until now, at least.

Original:
Eh… i det siste så… (2.0) har jeg brukt veldig mye tekstbok, eh… (2.0) for min del. Det har vært ganske mange andre fag som jeg har hatt – måttet jobbe med og, så jeg har liksom nedprioritert matte littegrann. Ehm (1.5) noe som har ført at jeg har ikke hatt tid til å se på videoer eller sette meg så godt inn i det som jeg egentlig har lyst til. Ehm, da blir det å (1.0) lese… i tekstbok for å skjønne liksom grunnprinsippene og så være i forelesningene. Ehm… (1.5) Eh… for jeg – for min del så… sitter det ganske bra. Etter å – hvis jeg (1.0) hvis jeg skjønner konseptet, altså hvor man henter ting fra, og sånne ting, som hvis det er vist i bok eller forelesning, så føler jeg at det sitter for min del. Da er det… (1.0) så lenge det er forståelig hvor… ting kommer fra, hvorfor (1.0) ting er satt der og der så pleier jeg å ta det ganske bra (1.0) bare ved å lese tekstbok. Eh, egentlig å ikk – da trenger jeg ikke å gjøre så mye oppgaver for å – i hvert fall ikke for å skjønne det da. For å bli god i det, så må jeg vel selvfølgelig gjøre litt mer oppgaver, men… (2.0) Akkurat frem til nå, så har det egentlig bare vært for å få – liksom henge med på forståelsesmessig del, i hvert fall, så heller i eksamensperioden ta opp igjen mer oppgaver, så… Mye tekstbok for tiden, ikke så veldig mye annet, sånn… (0.5) akkurat frem til nå i hvert fall.

Context:
Asked whether he had used any resources more or less than previously. This is the entirety of his answer.

<table>
<tr><td>Quote location:
Benjamin 2,4</td><td>Quote categorization:
Semi-prompted</td></tr>
<tr><td colspan="2">Translation:
Well, it is a bit random, and it is because the book is very good… explains quite well (1.0) and it is very good at showing (1.0) er, it usually shows quite well where things like values come from and refer to formulas that – that is refers to previous formulas and so on.

Original:
Ja, det er litt tilfeldigheter, også er det fordi boka er ganske bra… forklarer ganske bra (1.0) og den er veldig god til å vise (1.0) eh, den viser som regel ganske bra hvor ting kommer fra av verdier og henviser til formler som, altså tidligere formler også videre.</td></tr>
<tr><td colspan="2">Context:
Asked whether the changes reported are lasting or due to coincidences. This is at the start of his answer. He also talks about the important of seeing examples of exercises and not just theory.</td></tr>
</table>

<table>
<tr><td>Quote location:
Benjamin 2,5</td><td>Quote categorization:
Prompted</td></tr>
<tr><td colspan="2">Translation:
I: Ehm (1.0) when it comes to resources that you felt you had made your own last time, you mentioned last time that you first and foremost had (0.5) strategies for how you used the videos, like playing them fast, skipping, taking notes and rewatching. Ehm (1.0) is there more you would like to add to…?
B1: Ehm… No, not really.

Original:
I: Ehm (1.0) når det gjaldt ressurser du følte du hadde gjort til dine egne, så nevnte du sist at du først og fremst hadde (0.5) strategier for hvordan du brukte videoene, sånn å spille de raskt, spole, ta notater og se igjen. Ehm (1.0) er det noe mer du vil legge til…?
B1: Ehm… Nei, egentlig ikke.</td></tr>
<tr><td colspan="2">Context:
It was established at the start of the interview that the interviewer gave various summaries of Benjamin’s answers from the previous interview.</td></tr>
</table>

Quote location: Benjamin 2,6	**Quote categorization**:

Translation:
I: Ehm (4.0) when it comes to (0.5) like, working with others, you… (1.5) said that you feel like you learn a lot by working with people at the same level as you, butt hat you (1.0) mostly work alone, primarily because (0.5) ehm (0.5) spare time filled with training. Ehm (0.5) how correct is that… (1.0) as of now?
B1: Er, it is quite similar there, it is of course better to work with others than – when one solves exercises and such. Er, for me it often comes down to getting to explain to others (1.5) and it makes it so I get a better understanding of things (1.5) Ehm… (0.5) so what I usually – that is usually the best way to work for me personally, ehm… (1.0) but it takes a long time to go through exercises that way. Er, because… if one has to explain a lot or need a lot of explaining oneself, or stuff like that, then it is, like – an exercise takes a very long time and (1.5) I do not have that much time right now, so… then it is a lot (1.0) a lot of the same, but it is not just training, it is a lot – I am part of a union, I am chosen representative and so on, so (2.0) there is a lot to do.

Original:
I: Ehm (4.0) når det gjaldt (0.5) sånn å jobbe med andre, så… (1.5) sa du at du føler du lærer mye av å jobbe med folk på samme nivå, men at du (1.0) jobber mest alene, først og fremst grunnet (0.5) ehm (0.5) hverdag med mye trening. Ehm (0.5) hvordan stemmer det… (1.0) sånn per nå?
B1: Eh, det er ganske likt der, det er selvfølgelig best å jobbe med andre enn – når man løse oppgaver og sånn. Eh, for min del så går det ofte ut på at jeg får forklart for andre (1.5) og det gjør at jeg får en ganske bedre forståelse for ting (1.5) Ehm… (0.5) så det jeg pleier – det pleier liksom være den beste måten å jobbe for min del på, ehm… (1.0) men det tar veldig lang tid å gå igjennom oppgaver på den måten. Eh, fordi… hvis man må forklare mye eller man trenger forklaring selv, eller sånne ting så er liksom – tar en oppgave veldig lang tid og (1.5) jeg har ikke så god tid for tiden, så… da blir det litt sånn (1.0) litt det samme, men nå er det ikke bare trening, det er mye – jeg er med i linjeforening og jeg er tillitsvalgt også videre, så (2.0) det er mye å gjøre.

Context:
It was established at the start of the interview that the interviewer gave various summaries of Benjamin’s answers from the previous interview.

Quote location: Benjamin 2,10	**Quote categorization**: Unprompted
Translation: Well, I do not really like Maxima, right, so I would have liked to see that we got to use other resources, like emphasizing that we used, I don’t know, Matlab or something or other elsewhere (2.0) because I see the advantage to learning Maxima, to have like a… (1.0) calculation program, but exactly Maxima I feel is er… (1.5) not that good, you know. That is, like (1.0) there are very many who… struggles to see (2.0) what to say, the relations in it, and get – like (1.0) when you have not used Maxima a lot before, the learning curve is very steep Original: Ja, jeg liker ikke helt Maxima da, så jeg skulle gjerne sett at vi fikk brukt andre ressurser, altså lagt opp til at vi hadde brukt, jeg vet ikke, matlab eller et ellller annet andre steder (2.0) fordi, jeg ser fordelen med å lære seg Maxima, for å kunne et sånn… (1.0) regneprogram, men akkurat Maxima føler jeg er eh… (1.5) ikke helt bra altså. Altså sånn (1.0) det er veldig mange andre som… sliter med å liksom se (2.0) hva skal jeg si, sammenhengen i det, og så få – altså (1.0) når man ikke har brukt Maxima så mye før, så er det veldig bratt læringskurve	
Context: Asked if any resources are provided through web sites and if so, whether he used them. This is early in his answer, and constitutes approximately 50% of his answer. Before this he mentions MyMathLabs being emphasized. Afterwards he goes into details about finding it difficult to know what parameters Maxima requires for a given task.	

<table>
<tr><td>Quote location:
Benjamin 3,1</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
The purpose of this… point right here is… (1.5) It says interactice, and by that I mean things you can (1,5) er, what to say, change yourself, that is – where you can… interact, right, where you can change – for instance, simulations. That is, if you go online to find… (1.0) or at GeoGebra or whatever. That is to draw a graph and then you can, like, drag on those sliders or something, then see how things change when the values change and such. Simulations for shapes and such, how they change with – over time and bla bla bla, so… That is what I mean by those, and calculator, for me it is like (1.0) well, it is just to sit with a calculator and test different (0.5) theories and just… (1.0) Like… With that item I mean things that you can (1.5) what to say? (1.0) change and do something with on your own, right. […] It – the opportunity to ask questions (1.0) is important to include, because it… (1.5) It is something I… have a lot of use for, being able to ask a lot of stupid questions, because that is what (1.0) that helps – helps, for me at least.

Original:
Det som er hensikten med det… punktet her er… (1.5) Det står interaktive, og med det så mener jeg ting du kan (1.5) eh, hva kan man si, endre på selv da, altså sånn – hvor du kan… interagere, altså, hvor du kan endre på – for eksempel da, sånn simuleringer. Altså hvis du går på nett og finner en… (1.0) eller på geogebra eller whatever. Altså tegne en graf og så kan du liksom dra på noe sånn slides eller noe, så se hvordan ting endrer seg når verdier endrer seg og sånn. Simuleringer for figurer og sånn, hvordan de endrer seg med – over tid og bla bla bla, så… Det er det jeg mener med disse her, og kalkulator, for min del så er det sånn (1.0) ja, det å bare kunne sitte på en kalkulator og teste ut forskjellige (0.5) teorier og bare… (1.0) Sånn… Med det punktet der så mener jeg ting du kan (1.5) Hva skal man si (1.0) endre og gjøre noe med selv da […] Det – muligheten til å stille spørsmål (1.0) det er veldig viktig å ha med, for det… (1.5) Det er noe jeg… drar veldig nytte av, å kunne ha mulighet til å stille masse dumme spørsmål, for det er det som (1.0) det hjelper – hjelper for min del i hvert fall. Så… (1.0) det var det jeg kom på, så nå tror jeg det er ganske… (2.5) Tror ikke jeg kommer på så mye mer i hvert fall.</td></tr>
<tr><td colspan="2">Context:
Asked to describe the changes he made to his mind map. Not included is a section where he explains that he included the category to separate them from more passive resources.</td></tr>
</table>

Quote location: Benjamin 3,3	**Quote categorization**: Unprompted
Translation: Yeah, a bit perhaps. Used more… (0.5) the homework assistance we get in MyLabs. Er, used it more than I did at the start of the semester. Er, because, on the *homework* er… (1.5) *homework* exercises we have, there is the option to go through those examples and such… (2.5) of… (0.5) on those – for all the different exercises and such (1.0) there are many exercises there, or at least quite a lot, so one gets a bit of *mengdetrening**, (1.5) ways to test oneself. Original: Ja, litt kanskje. Brukt mer… (0.5) den leksehjelpen vi har på mylabs. Eh, brukt den mer enn jeg gjorde i starten av semesteret. Eh, fordi, på de *homework* eh… (1.5) *homework*-oppgavene vi har så er det mulighet for å gå igjennom sånne eksempler og sånn… (2.5) på sånn… (0.5) på disse – alle forskjellige oppgavene og så (1.0) er det masse oppgaver der, eller i hvert fall ganske mange så man får litt sånn mengdetrening, (1.5) varianter å teste seg på.	
Context: Asked if there had been any changes to how he used resources since the previous interview. This is at the start of his answer. He goes on to mention that some of the exercises are complex and that the explanation are of high quality. *Rough translation: practice by volume. Common term within the Norwegian School system for the idea that solving many exercises is important in order to learn.	

<table>
<tr><td>Quote location:
Benjamin 3,5</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">
Translation:
Mm… (3.0) not really. I try to work as efficiently as possible, because now it… exams are fast approaching, it… (1.5) and I mostly just want to focus on the other exams, (1.5) so I try to… like… (1.0) [deep inhale]* shorten down what I can, but… (2.0) it is nothing other than that I (1.0) try to make room for other things, so there is not anything… (2.0) Is nothing new, in that way, it.

Original:
Mm… (3.0) egentlig ikke. Jeg prøver å gjøre det så effektivt som mulig, for nå er det… eksamener som nærmer seg med stormskritt, det… (1.5) og jeg har egentlig mest lyst til å fokusere på andre eksamener, (1.5) så jeg prøver å… liksom… (1.0) [dypt innpust]* korte det ned det jeg kan, men… (2.0) det er jo ikke noe annet enn at jeg (1.0) prøver å få plass til andre ting, så det er ikke noe… (2.0) Er ikke noe nytt, sånn sett, det.</td></tr>
<tr><td colspan="2">Context:
Asked if he had any new strategies for how to use resources. This is the entirety of his answer.
*Sounds tired.</td></tr>
</table>

<table>
<tr><td>Quote location:
Benjamin 3,7</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">
Translation:
Well, at least on the introductions I see the whole thing, and then for the rest I skip to the parts where I am uncertain – uncertain to look at precisely the (1.0) steps that I am uncertain about. Er… (4.0) and then… (1.0) write it down – make sure to write it down – with own notes too. (2.0) As if it was a lecture and then (2.0) that is it, really.

Original:
altså i hvert fall på introduksjonene så ser jeg på hele, og så på de andre så skipper jeg til de delene hvor jeg er usikre – usikker for å se på akkurat de (1.0) overgangene jeg er litt i tvil på. Eh… (4.0) og så… (1.0) skriver det ned – passer på å få skrevet ned det – med egne notater også. (2.0) Som om det skulle vært en forelesning og så (2.0) er vel egentlig det det.</td></tr>
<tr><td colspan="2">Context:
Asked to go into detail on how he has used the video lectures. This is at the end of his answer and constitute about 20% of his answer. Also talks about how much the videos are emphasized in the course, how he thinks other students do not use them much and how he learns things easily when they are explained well, enabling him to understand mathematical relationships.</td></tr>
</table>

Quote location: Benjamin 3,8	**Quote categorization**: Unprompted
Translation: The first videos are always (1.0) made for introduction to (1.0) topics and, like, to see ‘what is this thing?’ and… (1.0) usually it also is… nicely put into a system where you can see (1.0) what it is used for and… (1.5) so on […] and hear a bit about how to decompose it and what it is used for and bla bla bla. Ehm… (1.5) And it is very useful to put it in perspective, right Original: De første videoene er alltid (1.0) lagt opp til sånn introduksjon til (1.0) tema og liksom for å se ‘hva er dette her for noe?’, og… (1.0) som regel også så er det… fint satt i system hvor man får se (1.0) hva det brukes til og… (1.5) også videre […] høre litt om hvorfor man skal ta det fra hverandre og hvordan det brukes og bla bla bla. Ehm… (1.5) Og det er veldig nyttig å sette ting i perspektiv da	
Context: Asked to elaborate on his use of the term ‘understanding’ and how it relates to the video lectures. He also talks about videos about examples and concludes that the focus is about “fifty-fifty” on understanding and examples, even though there are more videos on examples.	

Quote location: Benjamin 3,11	**Quote categorization**: Unprompted
Translation: You get an exercise, and then (1.5) you get… (1.5) er… (0.5) you insert and answer, then you either get right or wrong. If it is wrong, then it is like … (1.0) there is a hint, usually, right, that you have to use a formula or something, but it is like – that is the only feedback, so if you have used that formula, it does not help very much Original: Du får en oppgave, og så (1.5) får du… (1.5) eh… (0.5) så legger du inn et svar, så får du enten om det er riktig eller galt. Hvis det er galt, så er det liksom… (1.0) så står det sånn hint, som regel da, at du må bruke en formel eller noe, men det er liksom – det er den eneste tilbakemeldingen, så hvis du har brukt den formelen, så hjelper ikke det så veldig mye	
Context: Asked to describe the automated assessment in MyMathLabs. This is at the start of his answer. He also describes the similar exercise feature.	

<table>
<tr><td>Quote location:
Benjamin 3,12</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
For me it is really – am mostly concerned with if it is actu… – right or wrong, so in that sense it is… (5.5) In that sense it is – would like to have [laughs] actually how it is in MyLabs, just that you get more attempt on wrong answers

Original:
For min del så er det egentlig – mest opptatt av om det er fakt… – riktig eller galt, så sånn sett så er det jo… (5.5) Sånn sett så er det jo – skulle gjerne hatt [ler] egentlig sånn som det er i mylabs, bare du får flere forsøk på å gjøre feil</td></tr>
<tr><td colspan="2">Context:
Asked about the assessment hypothetical. This is at the start of his answer and constitute less than 20% of his answer. Also mentions the possibility to see if an incorrect answer is caused by minor errors and the potential downside to multiple attempts that one can get hung up on an exercise one gets wrong. Says that if he does not understand the exercise well enough to read a hint, then he probably is not prepared to solve it at all, so a hint is not helpful.</td></tr>
</table>

From interviews with Brage

<table>
<tr><td>Quote location:
Brage 1,1</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
Yes. Ehm, when we solve – we solve exercises as homework, like, in MathLab – or MyMathLabs. Er… and there I use very much the function with t… – for examples on how the exercise should be solved, and if I cannot do it then (1.0) er… (1.0) Then I s… – through, like a step by step where you so… – are part of solving an exercise when they, like, show how to do it. I use that quite a lot, and then… (1.0) I use the video lectures quite a bit. I think they are very nice, and very quick to look at, because you can play back faster than it is actually recorded (1.0) just to go through a topic quickly and see how you solve it. And if I do not - if I look through a video lecture and do not get it (1.0) or do not understand what he is talking about, then I usually do not… I go to the textbook, to get elaboration. Eh… (1.0) yeah. (1.0) So I really mostly use that feature in MyMathLabs when I solve (1.0) er… homework.

Original:
Ja. Ehm, når vi løser – vi løser jo oppgavene til hjemmelekse sånn på mathlab – eller mymathlabs. Eh… og der bruker jeg veldig mye funksjonen med t… – for eksempel på hvordan oppgaven skal løses, og hvis jeg ikke klarer å få det til da (1.0) eh… (1.0) så ser j… – gjennom sånn step by step der du l… – er med å løser oppgaven når de liksom viser hva du skal gjøre. Det bruker jeg veldig mye, og så… (1.0) bruker jeg en del av videoforelesningene. Jeg synes de er veldig greie, og veldig kjapt å se igjenom, for du kan spole raskere enn det det egentlig er spilt inn i (1.0) bare for å se raskt gjennom et tema og få vite hvordan man skal løse det. Og hvis jeg ikke - Hvis jeg ser gjennom en videoforelesning og ikke får det til (1.0) eller ikke skjønner hva han snakker om, så pleier jeg ikke gå i tekstboken da, for å få en utdypning. Eh… (1.0) Ja. (1.0) Så jeg bruker egentlig mest den funksjonen i mymathlab når jeg løser (1.0) eh… leksa.</td></tr>
<tr><td colspan="2">Context:
Asked an open question about how he uses resources for mathematics. This is the entirety of his answer.</td></tr>
</table>

<table>
<tr><td>Quote location:
Brage 1,2</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
Er… It has become like – more of like habits now, right, when I am used to using (0.5) er, use… [inaudible] examples and step by step solution in, ehm… MyMathLabs. Ehm… but usually I decide to – if it is a new topic, right, then I first decide to look through the video lectures (0.5) so that I, like, understand how to solve them and such and (0.5) if I come to – if I am solving an (1.0) exercise for homework that I am unable to do, then I go through the examples. If I still cannot do it, I look in the textbook or… videos about it so I understand how to solve it.

Original:
Eh… Det er blitt litt sånn – litt mer sånn vanesak nå da, når jeg er vant til å bruke (0.5) eh, bruke… [uforståelig] eksempel og steg for steg løsning i, ehm… mymathlabs. Ehm… men som regel så bestemmer jeg meg for at – hvis det er nytt tema da, så bestemmer jeg meg for å først se gjennom videoforelesningene (0.5) sånn at jeg liksom skjønner hvordan jeg skal løse det og sånn og… (0.5) Hvis jeg kommer opp – hvis jeg holder på å løse en (1.0) oppgave i leksene som jeg ikke får til så ser jeg igjennom eksemplene. Hvis jeg fortsatt ikke får det til, så ser jeg jo i boka eller… videoene om igjen sånn at jeg skjønner hvordan man løser det.</td></tr>
<tr><td colspan="2">Context:
Asked how he decides what resources to use. This is the entirety of his answer.</td></tr>
</table>

<table>
<tr><td>Quote location:
Brage 1,3</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
Yes, primarily I use what the course emphasizes, [Bjørnsen’s] video lectures mainly, and that MyMathLabs, but (0.5) er… occasionally I also search (1.0) for problems on the internet, or on Google. Er, or how for instance these matrix calculations work – certain rules and such, to get it quickly and nicely put. Er… (1.0) and I might also look at video lectures on YouTube from other people, to get a – like a (1.0) Er, a somewhat different angle on the problem, and solutions as well, for instance. But it happens usu… – or more often I use what the course emphasizes, right.

Original:
Ja, først og fremst så bruker jeg det som kurset legger opp til, [Bjørnsens] videoforelesninger hovedsakelig, og det mymathlabs, men (0.5) eh… det hender også at jeg søker (1.0) på problemer på internett, eller på google. Eh, eller hvordan for eksempel det her matriseregning fungerer – visse regler og sånn, for å få det kjapt og greit opp. Eh… (1.0) også kan jeg også se videoforelesninger på youtube fra andre folk, for å få en – lissom en sånn (1.0) Eh, en litt annen vinkel på et problem og løsninger óg, for eksempel. Men det hender som r… – eller som oftest bruker jeg jo det kurset legger opp til, da.</td></tr>
<tr><td colspan="2">Context:
Asked if he primarily use resources emphasized in the course and if he uses additional resources. This is the entirety of his answer.</td></tr>
</table>

<table>
<tr><td>Quote location:
Brage 1,4</td><td>Quote categorization:
Semi-prompted</td></tr>
<tr><td colspan="2">Translation:
If it does no… I feel that (0.5) it – the resources that the course emphasizes are not sufficient, that I do not quite understand (0.5) how to solve an exercise, or do not get it, then (0.5) I usually end up searching on Google or something, at least at first.

Original:
Hvis det ikk… føler at (0.5) det – de ressursene som kurset legger opp til ikke er tilstrekkelig, at jeg ikke skjønner helt (0.5) hvordan en oppgave skal løses, eller ikke får det til, da (0.5) hender det som regel at jeg søker på google eller noe sånn, først i hvert fall.</td></tr>
<tr><td colspan="2">Context:
Asked when he uses the other resources. This is the entirety of his answer.</td></tr>
</table>

<table>
<tr><td>Quote location:
Brage 1,5</td><td>Quote categorization:
Semi-prompted</td></tr>
<tr><td colspan="2">Translation:
Yes… yeah, well, of course it is (0.5) like, once you find a (1.0) er… good resource or web page for instance, then… (0.5) you often come back to it.

Original:
Ja… Ja, ja, det er jo (0.5) veldig sånn at hvis du først finner en (1.0) Eh… god ressurs eller nettside for eksempel så… (0.5) kommer man ofte tilbake igjen til den.</td></tr>
<tr><td colspan="2">Context:
Asked whether there was a relation between how much he liked a resource and how much he used it. This is at the start of his answer. He goes on to specifically talk about the video lectures.</td></tr>
</table>

<table>
<tr><td>Quote location:
Benjamin 1,8</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
I try to learn it myself (1.0) on my own, first, because I feel like I get more (1.0) from contemplating a problem and then figure it out, rather that to just get – be told the solution right away. But in other courses and such, then… then it is a bit – then, of course, I ask a bit more for help, perhaps.

Original:
Jeg prøver å lære meg det selv (1.0) på egen hånd først, for jeg føler jeg får mye mer (1.0) ut av å gruble på et problem, og så finne ut av det, i stedet for å bare få – bli fortalt løsningen med en gang. Men i andre fag og sånn så… så er det jo litt – så spør jeg jo litt mer etter hjelp, kanskje.</td></tr>
<tr><td colspan="2">Context:
Asked whether he asks questions of the lecturer or other university staff. This is the latter half of his answer. The first concerns what people are involved in the course that he could have asked.</td></tr>
</table>

<table>
<tr><td>Quote location:
Brage 2,1</td><td>Quote categorization:
Semi-prompted</td></tr>
<tr><td colspan="2">Translation:
I: So first, ehm (1.0) that MyMathLabs is what you use the most and that you value the step by step explanations. That… you use video lectures and go to the book if you are not quite satisfied with the explanations. Occasionally you Google something or go to YouTube to get multiple perspectives on things. After the videos you go (1.0) to work on exercises. If you run into problems, you look at s… – at examples in MyMathLabs and potentially check the textbook.
B2: Mm, yes it fits very well with (1.0) how I use… the tools. (2.0) Mm (0.5) so it is still the same… (0.5) that I do. Like, lately – for the last week we have had a Maxima project. Then I have used the textbook (1.0) the most (0.5) to look at the formulas I needed to use and such.

Original:
I: Så denne gangen så kommer jeg til å (1.0) prøve å oppsummere det du sa sist, og så vil jeg at du skal si litt om (0.5) hvor bra oppsummeringen stemmer og om det er noe som har endret seg siden den gang. Så først, ehm (1.0) at my mathlabs er det du bruker mest og at du setter stor pris på steg for steg forklaringer. At… du bruker videoforelesningene og går til boka hvis du ikke er helt fornøyd med forklaringene. Det hender også at du søker på google eller går til youtube for å få flere innfallsvinkler på ting. Etter videoene så går du (1.0) til arbeid med oppgaver. Om du får problemer så ser du f… – på eksempler i mymathlabs eller eventuelt går til læreboka.
B2: Mm, ja det stemmer veldig bra med (1.0) sånn som jeg bruker… hjelpemidlene. (2.0) Mm (0.5) så det er fortsatt det samme… (0.5) jeg gjør. Sånn, nå i det siste – denne uken så har vi hatt sånn Maxima prosjekt. Da har jeg brukt boka (1.0) mest da (0.5) for å se på formlene jeg trenger å bruke og sånne ting.</td></tr>
<tr><td colspan="2">Context:
Preceded by an explanation that the interviewer is attempting to summarize Brage’s statements from the first interview. When asked why the change had occurred, he said it was a bit random and simply quicker to look it up in the textbook.</td></tr>
</table>

Quote location: Brage 2,6	**Quote categorization**:
Translation: I: Ehm, last time you said that there was no resource that you felt like you had made your own. Would you still say that? B2: Yes… (1.0) I use them, I guess, how one is intended to use them, in a way, so… (1.0) I do not think I would say that I made them my own, really. Original: I: Ja. Ehm, sist sa du at det ikke var noen ressurser du følte du hadde gjort til dine egne. Vil du fremdeles si det? Brage: Ja… (1.0) Jeg bruker de vel sånn som det er lagt opp til at man skal bruke det på en måte, jeg… (1.0) Jeg vil nok ikke si at jeg har gjort det til mine egne helt.	
Context: It was established at the start of the interview that the interviewer gave various summaries of Brage's answers from the previous interview.	

Quote location: Brage 2,7	**Quote categorization**:
Translation: I: Ehm, so about (0.5) lecturer and working with others you (0.5) said that you (1.0) like to contemplate things on your own first, before you potentially ask the lecturer. And you work with others four to six hours a week and prefer to work with (0.5) two to three others. Would you say that that (0.5) fits well? B2: Yes. I feel like if I think – if I have a problem (0.5) and try to work on it on my own first, then I sort of learn the most, because then I have to, like, think how to solve it, rather than to ask 'how does one solve this' right away. Er… and… (0.5) About working with others, I work – I would say I work more than four hours with others, because there are (1.0) four hours throughout a week where we have lectures, and then I work with others during those hours. Er… (2.0) but felt that it fit quite well, yes, how I use it when I work. Original: I: Ehm, sånn angående (0.5) foreleser og jobbe med andre, så (0.5) sa du at du (1.0) liker å gruble på ting selv først, før du eventuelt spør foreleser. Og at du jobber med andre 4-6 timer i uka og foretrekker å jobbe med (0.5) 2-3 andre. Vil du si at det (0.5) stemmer ganske godt? B2: Ja. Jeg føler at hvis jeg tenker – hvis jeg har problem (0.5) og prøver å jobbe med det mest selv først, så på en måte lærer jeg mest, for da må jeg liksom tenke hvordan jeg skal løse det, i stedet for å bare spør hvordan løser man dette med en gang. Eh… og… (0.5) Det å jobbe med andre, så jobber jeg, jeg vil si at jeg jobber mer enn 4 timer sammen med andre, for det er (1.0) 4 timer i løpet av uka der vi har sånn forelesningstimer, og da jobber jeg med andre i de timene. Eh… (2.0) men følte at det stemte ganske bra, ja, sånn som jeg fortsatt jobber.	
Context: It was established at the start of the interview that the interviewer gave various summaries of Brage's answers from the previous interview.	

<table>
<tr><td>Quote location:
Brage 2,11</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
Right. Er, I feel like I got to s… – think and say – write down most of it last time. Er, it is very important to me, or I emphasize a lot on MyMathLabs, right (1.0) and the step by step solutions. And the part where one gets feedback on wrong answers. […] well, internet is what (0.5) is usually the place where I search if I… (1.5) to find a quick (1.5) er… [Writes] find a quick solution to one problem or another if there is something or other I wonder about or something, especially now that I have been working with… (1.0) Maxima […] and then to find other solutions or other explanations if I think video lectures are hard to understand and the tex… – textbook can be a little bit (0.5) heavy to read sometimes. Then it is usually (1.5) like YouTube [Writes] or something like that that I go to, to find a different explanation.

Original:
Ja. Eh, jeg føler at jeg fikk s… – tenkt eller sagt ned – skrevet ned det meste sist gang. Eh, det som er veldig viktig for meg, eller som jeg legger mest vekt på er jo MyMathLabs (1.0) og steg for steg løsningene. Og det med at man får tilbakemelding på feil svar. […] for internett er det (0.5) som regel det stedet jeg søker hvis jeg… (1.5) for å finne en kjapp (1.5) eh… [Skriver] finne en rask løsning på et eller annet problem hvis det er et eller annet jeg lurer på eller noe, spesielt nå som jeg har holdt på med… (1.0) Maxima […] og så for å finne andre løsninger eller andre forklaringer hvis jeg synes videoforelesningene er vanskelige å forstå og tes… – tekstboka kan være litt sånn (0.5) tung å lese innimellom. Da er det som regel (1.5) sånn youtube [Skriver] eller noe sånn der jeg går til, for å finne en annen forklaring.</td></tr>
<tr><td colspan="2">Context:
Asked to see if he would like to make any changes to his mind map and to talk about them if he does. Some sentences are not included here for being repetitive and long. Also not included are comments about using the textbook for elaboration and video lectures for a “quick look through”.</td></tr>
</table>

Quote location: Brage 3,3	**Quote categorization**: Unprompted
Translation: Er, now lately, I have been attending l… – lectures – or we have had more lec… –lectures (1.0) with [Bjørnsen] in class, or we have gotten an extra hour a week, right, where he goes through (0.5) problems that are relevant for exams and such. Original: Eh, akkurat nå i det siste så har jeg vært mer på f… – forelesning – eller vi har fått flere fore… –forelesninger (1.0) med [Bjørnsen] i timene, eller vi har fått en ekstra time i uka, da, som han går gjennom (0.5) oppgaver som er eksamensrelevant og sånn.	
Context: Asked if he used any resources more or less since the previous interview. This is at the start of his answers. He also sums up his strategies that he still uses related to video lectures and MyMathLabs.	

Quote location: Brage 3,6	**Quote categorization**: Unprompted

Translation:
Er, no, would not – maybe not say that I have found my own ways to use it, but (0.5) when I go through tests and such in MyMathLabs (0.5) er… then I always take – or after I am done, right, then I take *screenshot* of the exercises, so I will have it in a systematic way so I can easily go to check an exercises if there is something that I am stuck on. Er, I do the same with (1.0) all exercises that I think are hard, then I s… – *screenshoter** (1.0) the solution suggestion, right, so I will have a *step by step* walkthrough (1.0) of the exercise that I can easily find. Er… (0.5) so that is probably what I have made my own the most, right but (0.5) the rest I would say that I use the way it is *lagt opp*** for us to use, in a way.

Original:
Eh, nei, vil ikke – kanskje ikke si at jeg har funnet egne måter å bruke det på, men (0.5) når jeg går gjennom tester og sånn på mymathlabs (0.5) eh… så tar jeg alltid – eller etter jeg er ferdig, da, så tar jeg *screenshot* av oppgavene, sånn at jeg har det på en systematisk måte så jeg lett kan gå inn og se på en oppgave hvis det er noe jeg står fast på. Eh, det samme gjør jeg på (1.0) alle oppgaver som jeg synes er vanskelige så s… – *screenshoter* jeg (1.0) løsningsforslaget da, sånn at jeg har en *step by step* gjennomgang (1.0) på oppgaven som jeg raskt kan finne frem til. Eh… (0.5) så det er kanskje det som jeg vil si at jeg har gjort mest til mitt eget da, men (0.5) resten vil jeg si at jeg bare bruker sånn som det er lagt opp til at vi skal bruke det, på en måte.

Context:
Asked if there were any resources that he felt like he had made his own. This is the entirety of his answer
**screenshoter* is the result of him adding Norwegian grammar to the word screenshot, turning it into a verb.
** Translation note: The Norwegian term *å legge opp* is derived from the volleyball term for delivering a setter (a pass leading into a smash). It refers to doing an action X that you expect for someone else to respond to with a specific action Y.

<table>
<tr><td>Quote location:
Brage 3,7</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
It has been a bit harder recently, so I might say that I ask a bit more for help lately. Cooperates more with buddies and such.

Original:
Det har blitt litt vanskeligere nå i det siste, så jeg vil kanskje tro at jeg spør litt mer om hjelp nå i det siste. Samarbeider litt mer med kompiser og sånn.</td></tr>
<tr><td colspan="2">Context:
Asked how much he uses social resources compared to previously. This is at the end of his answer. He also says that he asks some questions to the lecturer in person or by e-mails.</td></tr>
</table>

<table>
<tr><td>Quote location:
Brage 3,12</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
And then it was pretty nice to look at the weekly statistics, we could see how many hours we had worked so one can get a bit… It a bit visually for yourself, how much you worked on the course. Because it is… (1.0) The teacher has said that we are to – it is recommended to work seven hours a week on math, but… (0.5) it is a bit difficult to reach it, while if you – unless it is a week with tests and such. [Inaudible]. So it is a bit nice to see, right, how much you have actually worked.

Original:
Og så var det ganske greit å se den ukesoversikten, vi kunne se hvor mange timer vi hadde jobbet sånn at du får litt… Får litt visuelt selv også, hvor mye du hadde jobbet med faget. For det er jo… (1.0) Læreren har sagt vi skal – det er anbefalt å jobbe syv timer i uka med matte, men… (0.5) det er litt vanskelig å nå opp på det, hvis man – med mindre det er uke med tester og sånn. [uforståelig]. Så det er litt greit å se, da, hvor mye du faktisk har jobbet.</td></tr>
<tr><td colspan="2">Context:
Asked about how he experienced filling information into the Studert app. This is in the middle of his answer.</td></tr>
</table>

From interviews with Casper

<table>
<tr><td>Quote location:
Casper 1,1</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
Right. Er, usually I d… – always start a new week by… reading through the curriculum. That is, look through the – we have, like an info page on mathematics, a course wiki, where it briefly covers the curriculum of the week, right. And then read through it quickly before I go to the overview lecture, right, where there is theoretical coverage of the weeks material. Er… and then… it is… (0.5) not – we do not have much until (0.5) we have interactive lectures, right (2.0) where we go through exercises along with a teacher, that is (1.0) the teacher brings an exercise, and then we attempt the exercise, and then the teacher goes through it. Er, and then I notice more what I can and cannot and try to work on the recommended exercises (1.0) er… (2.0) leading into… plenary, right, then I notice what I cannot, so I usually watch the plenary on video at home. Then I use mostly pencil and paper, right, and then (1.0) potentially Wolfram Alpha if er… (1.0) they are recommended exercises that I struggle with. Eh, and then for repetition it is often [Charlie's] YouTube videos or Kha… – Khan Academy.

Original:
Eh, pleier da ogs… – alltid å starte en ny uke med… å lese igjennom pensumet. Altså lese den – vi har sånn infoside på matematikk, sånn wikiside, der det står kort om pensumet for den uken da. Og så lese over det kjapt før jeg går i oversiktsforelesning, da, der det er teoretisk gjennomgang over ukens stoff. Eh… Og så… er det… (0.5) ikke – vi har ikke så veldig mye frem til (0.5) vi har interaktiv forelesning da (2.0) der vi går gjennom oppgaver sammen med en lærer, altså (1.0) læreren kommer opp med oppgave, og så prøver vi på oppgaven og så går læreren gjennom det. Eh, og da merker jeg mer hva jeg kan og ikke kan, og så prøver å jobbe med anbefalte oppgaver (1.0) eh… (2.0) frem til… plenumsregning da, da merker jeg hva jeg ikke kan så plenumsregningen pleier jeg å se på video og gjøre hjemme. Da bruker jeg egentlig mest penn og papir der da, og så (1.0) eventuelt Wolfram Alpha hvis eh… (1.0) det er anbefalte oppgaver som jeg sliter med. Eh, og så til repetisjon så er det gjerne [Charlie] sine youtube-videoer eller Kha… – Khan Academy.</td></tr>
<tr><td colspan="2">Context:
Asked an open question about how he uses resources for mathematics courses. Not included is the part where he asks whether lectures can be considered a resource, for which the answer is yes.</td></tr>
</table>

Quote location: Casper 1,8	**Quote categorization**: Unprompted
Translation: Er, I think the video lectures are very good, or the short clips where they go through exactly what you are unsure about, right. I think it is better as well (1.5) I am not a *fan* of the book. It (1.5) is a bit too (2.0) heavy (0.5) really, to get through. Original: Eh, jeg synes de videoforelesningene er veldig bra, eller de korte snuttene der de går gjennom akkurat det du er usikker på, da. Jeg synes det er bedre også (1.5) ja, er ikke så *fan* av den boken. Den (1.5) er litt for (2.0) tung (0.5) egentlig å komme gjennom.	
Context: Asked if there are any resources he likes or dislikes more than others. This is the entirety of his answer.	

Quote location: Casper 1,9	**Quote categorization**: Semi-prompted
Translation: It is quite strong, right. It… If I can find something that likes, that works, which usually is possible to find, then… I rather use that than something I do not like. Original: Den er ganske sterk da. Det… Hvis jeg kan finne noe jeg liker, som fungerer, som som oftest går an å finne, så… bruker jeg heller det enn noe jeg ikke liker.	
Context: Asked if there is a relation between what resources he likes and which ones he uses. This is the entirety of his answer.	

<table>
<tr><td>Quote location:
Casper 2,1</td><td>Quote categorization:
Prompted</td></tr>
<tr><td colspan="2">Translation:
I: I have written that every week you start by quickly reading through the wiki pages, then you go to the overview lecture, go to interactive lecture, do recommended exercises and go to plenary or watch videos. You use videos like YouTube or Khan Academy for repetition, use [Charlie’s] videos a bit, (1.5) find the book to be a bit heavy and do not use it much. If there is a topic that you need to learn better, you use videos, while you rather use Wolfram Alpha for individual exercises.
C1: That sounds quite right, really.

Original:
I: Jeg har skrevet at hver uke begynner du med å lese kjapt gjennom wikisider, så gå på oversiktsforelesning, gå på interaktiv forelesning, gjøre anbefalte oppgaver og gå på plenumsregning eller se videoer. Du bruker videoer som youtube of Khan Academy til repetisjon, bruker [Charlie’s] videoer en del, (1.5) opplever boken som litt tung og bruker den ikke så mye. Om det er et tema du trenger å lære bedre, bruker du videoer, mens du gjerne bruker Wolfram Alpha til enkeltoppgaver.
C1: Det høres ganske så riktig ut det.</td></tr>
<tr><td colspan="2">Context:
Preceded by an explanation that the interviewer is attempting to summarize Casper’s statements from the first interview. When asked if he used any resources more or less, said that he used the math lab more.</td></tr>
</table>

<table>
<tr><td>Quote location:
Casper 2,7</td><td>Quote categorization:</td></tr>
<tr><td colspan="2">Translation:
Er… If it – often if there are graphs that I am unsure about (1.0) or (1.0) things I want to check how a graph looked like or such, then I use it to draw the graph. Then I can see approximately where the answer will be.

Original:
Eh… Hvis det – gjerne hvis det er grafer jeg er litt usikker på (1.0) eller (1.0) ting jeg vil sjekke hvordan en graf ser ut eller noe sånn så bruker jeg den til å tegne opp grafen. Så kan jeg se sånn cirka hvor svaret skal være.</td></tr>
<tr><td colspan="2">Context:
Asked how he uses Wolfram Alpha. This is the entirety of his answer.</td></tr>
</table>

Quote location: Casper 2,8	**Quote categorization**: Prompted
Translation: I: I see. Ehm, last time you said that there was no resource that you… felt like you had made your own. (2.0) Do you have anything you would (1.0) add there? C1: Mm… what do you mean by that question, really? I: Ehm, it is like, if you (0.5) feel like you have found (1.0) ways to use it that no one has taught you. C1: No, not… (1.5) Not particularly, no. Original: I: Ja. Ehm, sist så svarte du at det ikke var noen ressurser du… følte du hadde gjort til dine egne. (2.0) Har du noe du vil (1.0) legge til der? C1: Mm… hva legger du helt i det spørsmålet, egentlig? I: Ehm, det er litt sånn, hvis du (0.5) føler du har funnet (1.0) måter å bruke det på som ingen har lært deg. C1: Nei, ikke… (1.5) Ikke spesielt, nei.	
Context: It was established at the start of the interview that the interviewer gave various summaries of Casper's answers from the previous interview.	

<table>
<tr><td>Quote location:
Casper 2,9</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
I: When it comes to working with others, have there been any changes to how much you work… with others, compared to alone.
C1: Mm… I have started working a bit more alone (1.5) on certain topics because… I have gotten a bit… – gotten a little diff… – to a different level than the ones one normally works with, so then one is often better of (0.5) working alone, at times. Still realize the value of working with others.

Original:
I: (4.0) Ehm… (1.5) Når det gjelder å jobbe med andre, har det skjedd noen endringer i hvor mye du jobber… med andre, sammenliknet med alene.
Casper: Mm… jeg har begynt å jobbe litt mer alene (1.5) på visse tema fordi… jeg har kommet litt a… – Kommet litt anne… – på annerledes nivå enn de man da vanligvis jobber med, så får man gjerne bedre ut av å (0.5) jobbe alene, til tider. Innser fortsatt verdien av å jobbe med andre.</td></tr>
<tr><td colspan="2">Context:
It was established at the start of the interview that the interviewer gave various summaries of Casper’s answers from the previous interview.</td></tr>
</table>

<table>
<tr><td>Quote location:
Casper 3,6</td><td>Quote categorization:</td></tr>
<tr><td colspan="2">Translation:
Er… It is more about me… going to try… to get more understanding in the overview lecture while I am there, rather than to note down everything, so try rather to note down the example, because it is mostly what one goes back to to (0.5) find again, right. It is not the definitions one (1.0) wond… – want to check again.

Original:
Eh… Det handler mer om det at jeg… skal prøve å… få mer forståelse i oversiktsforelesningen mens jeg er der, i stedet for å prøve å notere ned alt, så prøve mer å notere ned eksempelet, for det er mest det man går tilbake for å (0.5) finne igjen da. At det ikke er de definisjonene man (1.0) lur… – vil slå opp igjen.</td></tr>
<tr><td colspan="2">Context:
Asked to elaborate after his response to the previous question. He was asked whether any of his strategies regarding resources had changes and simply said that his strategies for how to take notes had changed and the rest was the same.</td></tr>
</table>

From interviews with Celine

Quote location: Celine 1,1	**Quote categorization**: Unprompted
Translation: Well, the textbook I guess may be what I go to first, right. So it (1.0) er, try to read in it, at least. [laughs] But it is a bit heavy to look up with, so (0.5) it becomes a bit less. And then the lecture that one attends (1.0) takes notes. Er, and… then, I guess it is (0.5) well, I guess it is when one needs to do exercises, right, and then it can be a bit of Google or (1.0) homepages and such. Original: Altså, læreboka er vel kanskje den jeg kommer til først da. Så den (1.0) eh, prøver å lese i den, i hvert fall. [ler] Men den er litt sånn tung å slå opp i, så (0.5) det blir litt mindre. Og så er det forelesning som man går i (1.0) tar notater. Eh, og… så er det vel (0.5) ja, det er vel det man trenger for å gjøre oppgaver da, og da kan det jo fort bli litt google eller (1.0) hjemmesider eller sånn.	
Context: Asked an open question about how she uses resources for mathematics courses. Not included is her asking for clarification on how open the question is.	

Quote location: Celine 1,2	**Quote categorization**: Unprompted
Translation: Ehm… (0.5) well, on our webpages, right, there are topic pages, where there is a lot of infor… – quite a lot of, ehm… (1.0) What to say? (1.5) Well, learning, I was about to say [laughs] – material, right. So there it is in Norwegian, so it is simpler. So… when I did an exercise I – last week, I looked it up to… (0.5) check there instead of – one does not always bring the textbook and such, right, so it is quite nice. Original: Ehm… (0.5) nei altså inne på hjemmesiden vår da, så er det sånn temasider, der det ligger ganske mye, infor… – ganske mye, ehm… (1.0) Hva heter det? (1.5) Ja, læring, hold jeg på å si [ler] – stoff da. Så der ligger det på norsk, så det er litt enklere. Så kan man enklere finne akkurat det man vil se. Så… når jeg gjorde en oppgave så – forrige uke, så slo jeg opp da for å… (0.5) sjekke der i stedet for å – det er ikke alltid man har med boka og sånn, så det er veldig greit.	
Context: Asked to give examples of what she mentioned in her response to the previous question (see above). This is the entirety of her answer.	

Quote location: Celine 1,6	**Quote categorization**: Unprompted
Translation: Er… (1.5) I do not know it is quite – quite what you mean, right, but we have a plenary session where a person goes through exercises, and I think I learn more if I – because videos are put up afterward, so then, like, I do an exercise and then I see him do that exercise, so I make, like, my own thing, if you can call that a resource. So then, rather than sitting there and hearing all the exercises at once, it like (0.5) becomes more interactive – for myself, right. Original: Eh… (1.5) Jeg vet ikke om det helt – det blir helt det du mener da, men vi har sånn plenumsregning der en person går gjennom oppgaver, og jeg tror nok at jeg lærer mer hvis jeg – for det blir lagt ut videoer etterpå, så da, liksom, gjør jeg en oppgave og så ser jeg han gjøre den oppgaven, så jeg lager en sånn egen greie, hvis du kan kalle det en ressurs. Så da, i stedet for å sitte der og høre alle oppgaver på en gang, så liksom (0.5) blir det en litt interaktiv – for meg selv da.	
Context: Asked if there are any resources she feels like she has made her own. This is the entirety of her answer.	

Quote location: Celine 1,14	**Quote categorization**: Unprompted
Translation: But if you want more such examples of use, then I remembered that, er (1.0) [inaudible] from secondary, so GeoGebra is, like, pretty close, so I – if one – like, last week there was an exercise I did not understand why I got wrong, so then it was to use GeoGebra to check why I got it wrong. It was integration, right. So could, like, check if – where the mistake was, right. And, like, divide the exercise and such. So I use it a bit to check, right. Original: Men hvis du vil ha flere sånne eksempler på bruk så kom jeg på at, eh (1.0) [uforståelig] fra videregående enda, så geogebra ligger liksom ganske tett, så jeg – hvis man – sånn som forrige uke så var det en oppgave jeg ikke skjønte hvorfor jeg fikk feil, så da var det greit å bruke geogebra til å sjekke hvorfor jeg fikk feil. Det var en integrasjon, da. Så kan liksom sjekke om – hvor feilen ligger, da. Og ta liksom, dele opp oppgaven og sånn. Så jeg bruker det litt til å sjekke da.	
Context: Asked to see if she wanted to make any changes to her mind map and talk about them. After doing so, adds to a previous question about examples on how she uses various resources.	

Quote location: Celine 2,1	**Quote categorization**: Prompted
Translation: I: What I have written is that you use the textbook, but think it is a bit cumbersome for looking things up, that you attend lectures and take notes. When you work on exercises, you sometimes use Google or check the topic pages at [Charlie's] website. You also sometimes use GeoGebra, particularly for exercises that you got wrong at first. C2: Yes… Would say so, yeah. Original: I: Ja. Denne gangen så er det lagt opp sånn at jeg har prøvd å oppsummere det du sa sist (1.0) og… vil høre om (0.5) det er noe som har endret seg, eller noe du vil rette på med oppsummeringen. Det jeg har skrevet er at du bruker læreboka, men synes den er litt tung å slå opp i, at du går på forelesninger og tar notater. Når du jobber med oppgaver så hender det at du googler eller sjekker temasidene på [Charlie's] nettsider. Og det hender også at du bruker geogebra, spesielt på oppgaver det du først har fått feil. C2: Ja… Vil si det, ja.	
Context: Preceded by an explanation that the interviewer is attempting to summarize Celine's statements from the first interview. When asked if she used any resources more or less, said that she used Google a bit more recently.	

Quote location: Celine 2,8	**Quote categorization**: Prompted
Translation: I: Right. Ehm (1.0) when it comes to finding your own ways to use resources, you (1.0) said that you… use plenary videos to solve every exercise on your own first and then look through (0.5) plenary videos. Er (1.0) do you have anything to add to that? C2: No, I still do that. Because I feel like I learn more by thinking, and not just… be there and listen, right. Original: I: Ja. Ehm (1.0) når det gjelder å finne egne måter å bruke ressurser på, så (1.0) sa du sist at du… bruker plenumsvideoene ved å løse hver oppgave på egenhånd først og så se gjennom (0.5) plenumsvideo. Eh (1.0) har du noe mer du vil legge til på den? C2: Nei, jeg gjør fortsatt det. For jeg føler at jeg lærer mer av å tenke, og ikke bare… være der og høre, da.	
Context: It was established at the start of the interview that the interviewer gave various summaries of Celine's answers from the previous interview. Followed by the interviewer asking for clarification whether she alternates between solving exercises and looking at the plenary videos. She confirms that, but says that on occasion, she may skip straight to the plenary video if an exercise is difficult.	

Quote location: Celine 2,10	**Quote categorization**: Prompted
Translation: I: Mm. Ehm, when it comes to working with others and asking questions and such, I have written that you (0.5) ask a few* questions to student assistants, which are concrete questions about exercises, and that you work four to five times a week with everything from two to seven fellow students (2.0) Does that fit rather well? C2: Yes… Well, I would not say that I ask many questions to student assistants, it is a bit like – a bit, right, but not… (1.0) very much. Original: I: Mm. Ehm, når det gjelder å jobbe med andre og stille spørsmål og sånn, så har jeg skrevet at du (0.5) stiller en del spørsmål til studentassistenter, som er konkrete spørsmål om oppgaver, og at du jobber 4-5 ganger i uka med alt fra to til syv medstudenter. (2.0) Stemmer det sånn ganske bra? Celine: Ja… Altså, jeg vil ikke si jeg stiller så mange spørsmål til studentassistenter, det er litt sånn – litt da, men ikke… (1.0) veldig masse.	
Context: It was established at the start of the interview that the interviewer gave various summaries of Celine's answers from the previous interview. *The Norwegian *en del*, referring to an extent, is a bit vague. It can be understood as 'a few', but also as 'quite a few'. Hence, Celine felt the need to preface that it should be interpreted as a few in this case.	

Quote location: Celine 2,11	**Quote categorization**: Unprompted
Translation: And then we have, that prioritized time for math lab (0.5) on Tuesdays, so I usually go there, right, and then maybe more (0.5) slightly dependent on (0.5) time and what others do and such. Original: Og så har vi sånn prioritert tid på mattelab (0.5) på tirsdager, så jeg pleier å være der da, og så kanskje mer (0.5) litt ettersom (0.5) tiden og hva de andre gjør og sånn.	
Context: Asked to describe various aspects of the course. This is in the middle of her answer. She also talks about the number of Maple TA tests and mandatory assignments, and how many students need to pass, other organized sessions that the course provides, recommended exercises and the resources available on the web pages.	

Quote location: Celine 3,3	**Quote categorization**: Unprompted
Translation: Er, think it is quite similar (1.5) yeah. Er… I guess I (1.0) or yeah. Now, this year, I have a math course where perhaps (1.0) I use student assistants more and such, I think. So, (1.5) it depends a bit on the courses, in a way. Original: Eh, tror det er ganske likt (1.5) ja. Eh… Jeg har jo (1.0) eller ja. Nå, i år da, så kanskje jeg har et mattefag der jeg (1.0) bruker enda mer studentassistenter og sånn, tror jeg. Så, (1.5) det kommer litt an på fagene, på en måte.	
Context: Asked whether any of her strategies for how to use resources had changed. This is the entirety of her answer. When asked to elaborate, said it was because the new course provided fewer resources on the web pages than the previous mathematics course.	

From interviews with Christian

<table>
<tr><td>Quote location:
Christian 1,1</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
Well, first and foremost I use the most obvious resources, I guess. Pencil and paper and calculator to take notes and to solve exercises. I usually go to the lectures and at the same time I read the books, which I do to get (1.0) the most out of the lectures, so I read the bo… – so I read the textbook before the lecture and then then I take notes in the lecture. If there is something I don’t understand, I usually talk to professor slash lecturer or discuss with friends, potentially googling it afterwards. Other than classes I usually do exercises. I normally (0.5) either work in groups, alone or go to group work lessons. And then I often watch youTube videos about math.

Original:
Ja, først og fremst så bruker jeg vel det mest åpenbare av ressurser. Penn og papir og kalkulator til å ta notater og til å løse oppgaver. Forelesninger pleier jeg som regel å dra på samtidig som jeg leser bøkene og det gjør jeg for å få det meste ut av forelesningene, så jeg leser bø – så jeg leser pensumboka i forkant av å dra på forelesning, og så tar jeg notater på forelesning. Hvis det ikke er noe jeg forstår pleier jeg som regel å snakke med professor skråstrek foreleser eller diskutere det med venner, eventuelt google det på egenhånd i etterkant. Annet enn timer så pleier jeg å gjøre oppgaver. Da pleier jeg å enten jobbe i grupper, alene, eller dra på fellesregningstimer. Og så pleier jeg veldig ofte å se på youtube-videoer om matte.</td></tr>
<tr><td colspan="2">Context:
Asked an open question about how he uses resources for mathematics courses. This is the entirety of his answer.</td></tr>
</table>

<table>
<tr><td>Quote location:
Christian 1,3</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
Er… today we had lectures. Then I talked to my friends in the break about what we had gone through and then I did not get it, right, so I talked to the lecturer about it, and then… Ehm, yeah. Yeah, I guess that’s it.

Original:
Eh, i dag hadde vi jo forelesning. Da snakket jeg med vennene mine i pausen om det vi hadde gått igjennom og så skjønte jeg det ikke da, så jeg snakket med foreleseren om det, og så… Ehm, ja. Ja, det er vel egentlig det.</td></tr>
<tr><td colspan="2">Context:
Asked to give recent examples related to the resources he had mentioned so far. This is the entirety of his answer.</td></tr>
</table>

<table>
<tr><td>Quote location:
Christian 1,4</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
It is a mixture of what the university says we are to do and a mixture of something I know works myself, from secondary, where I used to – In secondary I used to – after I had gone to class I used to go through the curriculum in the book, and I thought it worked well to (0.5) get an alternate explanation in addition to some repetition, while now I have started trying to do it first, so that I get more time for pure exercise solving after having been dealt the curriculum. So… (0.5) yeah.

Original:
Det er en blanding av det universitetet sier at vi skal gjøre og en blanding av noe jeg vet fungerer selv, fra videregående, hvor jeg pleide å – på videregående pleide jeg i etterkant av å ha dratt på timen så pleide jeg å gå gjennom pensum i boka og det synes jeg fungerte ganske bra for å få en alternativ forklaring i tillegg til litt repetisjon, mens nå har jeg begynt å prøve å gjøre det i forkant slik at jeg har mer tid til ren oppgaveløsning i etterkant av å ha blitt utdelt pensumet. Så… Ja.</td></tr>
<tr><td colspan="2">Context:
Asked how he had discovered the various resources he used. This is the entirety of his answer.</td></tr>
</table>

<table>
<tr><td>Quote location:
Christian 1,5</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
I have a resource I often use that is very genuinely me, I feel, and it is that I often write stuff on the windows at home, so the windows at home are filled with mostly math exercises and a couple fun facts, quotes and stuff that I have with my roomen, but when I solve difficult exercises that are quite long, if I do no… – if I see that it will – that there is a chance to make a mistake, then I will write it on the window first, where it is easier to erase and edit things and… and then I usually write it down in my book afterwards. And then it is more fun to write on the windows, of course.

Original:
Jeg har en sånn ressurs jeg pleier å bruke som er veldig genuint meg, føler jeg, og det er at jeg pleier å skrive opp ting på vinduene hjemme, så vinduene hjemme er fyllt av mest matteoppgaver og et par fun facts, sitater og ting som jeg har med roomen min, men når jeg løser vanskelige oppgaver som er ganske lange. Hvis jeg ik… – hvis jeg ser at det kommer til – at det er sjanse for at jeg gjør feil, så pleier jeg først å skrive det opp på vinduet, der er det lettere å hviske ut og endre på ting og … og så pleier jeg å skrive ned i boka mi i etterkant. Og så er det mye morsommere å skrive på vinduet selvfølgelig.</td></tr>
<tr><td colspan="2">Context:
Asked if there are any resources he felt like he had made his own. This is the entirety of his answer. The word roomen is the result of him shortening and adding Norwegian grammar to the word roommate.</td></tr>
</table>

Quote location: Christian 1,6	**Quote categorization**: Unprompted
Translation: I think, er… (0.5) the textbook is pretty nice, and then I think exercises are essential. It comes from math being a repetition course and if you don't do the exercises you are *fucked* on exams. And you will not learn anything either, if you don't do exercises, so… it… Lectures I could do without, but it is ideal to get two different viewpoints on the same thing, two different explanations. Original: Jeg syns, eh… Pensumboka den synes jeg er ganske greit, og så synes jeg at oppgaveregning er essensielt. Det kommer fra at matte er et repetisjonsfag og hvis du ikke gjør oppgaver så er du *fucked* på eksamen. Og du kommer ikke til å lære hvis du ikke gjør oppgaver heller, så… Det. Forelesninger kunne jeg klart meg uten, men det er ideelt å få to forskjellige synspunkt på samme ting, eller to forskjellige forklaringer.	
Context: Asked if there are any resources he likes or dislikes. This is the entirety of his answer.	

Quote location: Christian 1,14	**Quote categorization**: Unprompted
Translation: Then we also have internet, where we have Wolfram Alpha. It is quite *alright* for calculating things, graphing things, finding inverse function, everything really. And then on occasion, I will google a proof, as well. Original: Så har vi også internett, der har vi Wolfram Alpha. Den er ganske allright til å kalkulere ting, grafe ting, finne inversfunksjoner, alt mulig rart egentlig. Og så hender det at jeg googler bevis en gang iblant, i tillegg.	
Context: Asked to describe his mind map. This is at the end of his answer and constitute about 15% of his answer.	

<table>
<tr><td>Quote location:
Christian 2,1</td><td>Quote categorization:
Prompted</td></tr>
<tr><td colspan="2">Translation:
I: Ehm… (1.0) I wrote that you read the book before lectures, take notes during the lecture and ask the lecturer (1.0) or friends if there is something you are wondering about. You work on exercises either alone, in a group or during group sessions, often watch YouTube about math, but not necessarily curriculum, use Wolfram Alpha a bit, for instance to plot things. Sometimes you Google something. Er, you have not needed it yet, but have considered using (0.5) Khan Academy and YouTube when something becomes difficult. Have not used the summaries or compendium yet, and are not sure whether you will use them. Prefers two different explanations to things, for instance through lecture and textbook. [Christian claps] So… does it fit well?
C3: Mhm, it was actually surprisingly accurate.

Original:
I: Ehm… (1.0) Jeg skrev at du leser boka før forelesning, tar notater under forelesning, og spør foreleser (1.0) eller venner om det er noe du lurer på. Du jobber med oppgaver enten alene, i gruppe, eller på fellesregningstimer, ser ofte på youtube om matte, men ikke nødvendigvis pensum, bruker Wolfram Alpha en del for eksempel til å plotte ting. Det hender at du googler noe. Eh, du har ikke trengt det ennå, men har tenkt å bruke (0.5) Khan Academy og youtube når noe blir vanskelig. Har ikke brukt sammendrag eller kompendiet ennå, og er ikke sikker på om du kommer til å bruke dem. Foretrekker å få to forskjellige forklaringer på ting, for eksempel gjennom forelesninger og lærebok. [Christian klapper] Så… stemmer det ganske bra?
C3: Mhm, det er faktisk overraskende accurate.</td></tr>
<tr><td colspan="2">Context:
Preceded by an explanation that the interviewer is attempting to summarize Christian’s statements from the first interview. When asked if he uses any resources more or less, says that he has asked friends more because the curriculum has been harder to understand.</td></tr>
</table>

Quote location: Christian 2,7	**Quote categorization**: Prompted

Translation:
I: Er, about resources you feel like you have made your own, you said that you (0.5) often wrote on the windows at home, especially when exercises (0.5) looked like they would be… long and difficult. Ehm, are there any more (1.0) you can think of, or… new…?
C3: Mm, I still do that, but other than that, then… (1.0) it looks pretty empty.

Original:
I: Eh, når det gjelder ressurser du føler du har gjort til dine egne, så sa du at du (0.5) ofte skrev på vinduene hjemme, spesielt når oppgaver (0.5) så ut til å bli… lange og vanskelige. Ehm, er det noen flere (1.0) du kan komme på, eller… nye…?
C3: Mm, jeg gjør fortsatt det, men annet enn det så… (1.0) ser det litt tomt ut.

Context:
It was established at the start of the interview that the interviewer gave various summaries of Christian's answers from the previous interview.

Quote location: Christian 2,8	**Quote categorization**: Semi-prompted

Translation:
I: Mm. Ehm… (1.0) about studying with others, you said that you study two to three times a week, with between two and four others. Ehm, when you work with others you usually sit in a big group, but you mostly work with one other person. (2.5) So, is it about the same?
C3: Yes, it… sounds – maybe I work (0.5) a bit more with – or when I sit with three or four people, like, it happens that we all work on the same, but, er… it is pretty random (0.5) what people work on.

Original:
I: Mm. Ehm… (1.0) når det gjaldt å studere med andre, så sa du at du studerer to til tre ganger i uka, med mellom to og fire andre. Ehm, når du jobber med andre så sitter dere som regel i en stor gruppe, men du jobber mest med en til. (2.5) Så, er det sånn cirka det samme.
Christian: Ja, det… høres – kanskje jeg jobber (0.5) litt mer med – eller når jeg sitter med 3-4 stykk, liksom, så hender det at alle jobber på det samme, men, eh… det er veldig tilfeldig (0.5) på hva folk jobber med.

Context:
It was established at the start of the interview that the interviewer gave various summaries of Christian's answers from the previous interview.

Quote location: Christian 2,13	**Quote categorization**:

Translation:
Er… (3.0) summary slash compendium… (0.5) I guess I have not used – I do not think I will use it for exams either. So I will cross that off. (11.0) Well, it seems quite correct, really.

Original:
Eh… (3.0) sammendrag skråstrek kompendiet… (0.5) har jeg vel ikke brukt – jeg tror ikke jeg kommer til å bruke det på eksamen heller. Så det krysser jeg også ut. (11.0) Ja, det her virker ganske korrekt, egentlig.

Context:
Asked to see if he would like to make any changes to his mind map and to describe them. This is at the end of his answer. He also talks about changing math studying friends to friends (because he also ask friends in the engineering program) and changing googling proof to just Google, because he has used Google to find something else as well.

Quote location: Christian 3,1	**Quote categorization**:

Translation:
Under internet we have Google and Wolfram Alpha. Google I use (0.5) like if suddenly I have forgotten a trigonometric identity. So I still use that, and Wolfram Alpha I still use to a large degree […] Calculator I have started using to a smaller degree, just because when I work I usually have the PC available, so I usually just use Wolfram Alpha as a calculator.

Original:
Under internett har vi google og Wolfram Alpha. Google bruker jeg (0.5) type sånn plutselig hvis jeg har glemt en trigonometrisk identitet. Så det bruker jeg fortsatt, og Wolfram Alpha bruker jeg fortsatt i stor grad […]Kalkulator har jeg begynt å bruke i litt mindre grad, bare fordi at når jeg jobber så har jeg som regel PC-en tilgjengelig, så jeg pleier bare å bruke Wolfram Alpha som en kalkulator.

Context:
Asked to see if he would like to make any changes to his mind map and to describe them. This is about 20% of his answer. He also talks about YouTube and Khan Academy, the textbook, lectures, lecture notes, previous exam sets, fellow students and the lecturer, coming to the conclusion that apart from the addition of previous exam sets, his strategies regarding them are largely the same.

<table>
<tr><td>Quote location:
Christian 3,3</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
Yes. Or… (2.0) er… (1.0) the difference between when I work during the exam period and when I work normally, it is that in the exam period I usually just do exam sets, and if I notice that there is something I am weak at, I might happen to (0.5) go to, for instance, Khan Academy and look for it or YouTube, or just read the book, or do a lot of exercises on the topic in the book, but mainly I use former exams as a jumping point during the exam period, (1.0) er, and throughout the rest of the year, I usually just work (0.5) with (0.5) those things, in a way.

Original:
Ja. Eller… (2.0) eh… (1.0) Forskjellen mellom når jeg jobber i eksamensperioden og når jeg jobber til vanlig så er det at i eksamensperioden så pleier jeg kun å gjøre eksamenssett, og hvis jeg merker at det er noe jeg er veldig svak på, så kan det hende jeg (0.5) går på for eksempel Khan Academy og leter etter det eller youtube, eller bare leser i boka, eller bare gjøre masse oppgaver på det tema i boka, men hovedsakelig så tar jeg utgangspunkt i å gjøre tidligere eksamener i eksamensperioden, (1.0) eh, og i løpet av året ellers, så pleier jeg bare å jobbe (0.5) med (0.5) de tingene her, på en måte.</td></tr>
<tr><td colspan="2">Context:
Asked to talk about resources that he had used more or less recently. This is the entirety of his answer.</td></tr>
</table>

Quote location: Christian 3,8	**Quote categorization**: Unprompted
Translation: Er… standard… (0.5) right wrong type problems (1.0) I actually hate to a high degree. We have it at the moment, and it is awful, because… Sometimes I get it wrong and then it is, either, for instance (0.5) the syntax I have entered is wrong, or it is like… well, typed a number wrong or it is, that I have done a slouch error in the book, or something. I do not know what it is, so I end up having to do the exercise over again. Often multiple times. Hate it. Original: Eh… standard… (0.5) rett galt type programmer (1.0) hater jeg egentlig i ganske stor grad. Vi har det for øyeblikket, og det er helt grusomt, fordi… Det hender at jeg får feil og så er det, enten så er for eksempel (0.5) syntaksen jeg har tastet inn feil, eller så er det sånn… ja, tastet et feil tall eller så er det, jeg har gjort en slurvefeil i boka, eller noe. Jeg har ikke peiling på hva det er, så jeg ender opp med å måtte gjøre oppgaven på nytt. Ofte multiple ganger. Hater det.	
Context: Asked about the assessment hypothetical. This is at the start of his answer and constitute about 40% of his answer. Also says that he would have used correct answer very little, used the hint option more and that he loves detailed solutions.	

<table>
<tr><td>Quote location:
Christian 3,10</td><td>Quote categorization:
Unprompted</td></tr>
<tr><td colspan="2">Translation:
Used it quite a lot to find… Last semester we had (0.5) the volume of (1.0) that and that rotational bodies I was about to say, (1.5) and (0.5) then, then you cannot plug it into the calculator, but in Wolfram Alpha it is possible. If I had gotten an answer that did not work with the answers, I would type it in there to check – or to sort of figure out where the error lies (1.0) by condensing (0.5) the expression.

Original:
Brukte det veldig mye for å finne… I forrige semesteret så hadde vi (0.5) volumet av (1.0) den og den omdreiningslegemer holdt jeg på å si, (1.5) og (0.5) da, da går det ikke an å plugge det inn på kalkulator, men på Wolfram Alpha går det an. Hvis jeg hadde fått et svar som ikke fungerte i forhold til fasiten, så ville jeg taste det inn der og sjekke – å på en måte finne ut av akkurat hvor feilen ligger (1.0) ved å innsnevre (0.5) uttrykket.</td></tr>
<tr><td colspan="2">Context:
Prior to the interview, was asked to bring a computer and demonstrate how he used Wolfram Alpha. This is at the end of his answer and constitute about 20% of his answer. He also talks about using Wolfram Alpha to find the derivative of functions, and a recent task to find the sum of all the fifth roots of unity. He was unable to solve the task with Wolfram Alpha and used Google instead.</td></tr>
</table>

Appendix J: All resources mentioned in the thesis

Calculator: Scientific calculators were used by the student at each of the universities.

Canvas: Digital learning platform. Mentioned by me as an example when asking students about digital learning platforms. Used at Universities Alpha and Beta.

Casio FX-9860GII: Adrian's scientific calculator, which he mentioned by name.

Compendium: Mentioned by Christian as a resource he at one point planned to use, but never did. Not mentioned by anyone as an emphasized resource.

Course page: At University Charlie, the course has a web page, which contains various information, such as the recommended exercises for a week, video lectures and examples of solution of exercises. Sometimes referred to as the 'math wiki'.

E-mail: Mentioned by Brage as something he occasionally used to ask questions to the lecturer.

Exam sheet: At University Alpha, students were allowed to write their own notes on an A4 sheet of paper, which they were allowed to use as a resource during the exam.

Excel: Program included in Microsoft's Office packages. Can be used to make mathematical spreadsheets.

Exercises: Mathematical tasks available either in the textbook or from MyMathLabs, which were not part of tests or mandatory assigments. Emphasized by each university and used by all the students. However, Benjamin did not do many exercises at the start of the semester.

Fellow students: Working with or asking questions of other students taking the same course. In the case of Christian, also includes discussion with friends who studied in mathematics programs rather than engineering programs.

Formula collection: At universities Alpha and Charlie, certain formula collections were allowed to use at the exams, and students used them when preparing for exams.

Fronter: Digital learning platform. Mentioned by me as an example when asking students about digital learning platforms. Not used at any university in the project.

GeoGebra: Program which includes dynamical geometry environment, computer algebra systems, spreadsheets and more (website: https://www.geogebra.org/?lang=en). Used a lot by Norwegian schools at secondary level.

Google: Specifically the Google search engine, used by many students (particularly at University Beta and University Charlie) to find information.

Group sessions: Organized sessions in which students at University Beta may work on group tasks.

Homework help: Mentioned by Andersen as an organized session where the students of the course could get help from older students. Not mentioned by any of the students in the study.

Khan Academy: A selection of educational videos within the STEM fields. Videos are hosted on YouTube, but the website (https://www.khanacademy.org/) and applications for smart phones and tablets organize the videos by field and by topic.

Interactive lecture: At University Charlie, the second lecture of a given week was focused on students getting to solve exercises in groups, with support from the lecturer. Bjørnsen described the idea of the lecture as partially based on the flipped classroom principle.

Internet: Students occasionally refer to the internet as a resource without going into specifics. Often, it seems likely that they mean using an internet search engine. For students at University Charlie, they may refer to the course pages as well.

Laptop: Only mentioned as a resource once, in one of the study sessions Christian filled into the Studert app.

Lecture: Each course included lectures. All students attended some lectures, but Andreas eventually started watching the videos of the lectures instead after a certain point.

Lecture notes: Notes taken by the students while attending a lecture or watching a video of a lecture.

Lecture streaming/videos: Andersen's lectures at University Alpha were streamed live and made available afterwards. Andreas used the streaming instead of the lectures after a certain point.

Lecturer: Many students asked questions of the lecturer, although they usually only did so after asking fellow students without finding a satisfactory answer.

Lecturer's notes: Andersen conducted lectures by re-writing his preparation notes and projecting the process onto a canvas. His notes were made available to students afterwards.

Maple TA: Used at University Charlie for weekly assignments. Includes a computer aided assessment feature. Considered difficult to use by Casper, who complained about syntax issues resulting in false negatives.

Math lab: A student support center at University Charlie. Each group of students had one time slot a week when they were prioritized, but students could also visit outside the time slot. Used by …

Math wiki: What the students tended to call the course page at University Charlie. Contains various information, such as the recommended exercises for a week, video lectures and examples of solution of exercises.

Mathcenter: Web page with a collection of resources, including text, video and more (URL: http://www.mathcentre.ac.uk/). Mentioned by Bjørnsen as one of the resources students were made aware of. Not mentioned by any student participant.

Matlab: Programming tool for mathematics. Mentioned by Adrian as a resource he likes, and would use if it was available for free. Mentioned by Benjamin as something that may be a better alternative than Maxima for programming in the course.

Maxima: Programming tool for mathematics used in the course at University Alpha. Described by Benjamin as a resource he disliked using because it was hard to understand without prior experience using it.

Mediasite: Web page for educational video streaming (URL: https://www.mediasite.com/) Used for streaming videos at University Alpha (see videos of lectures).

MyMathLabs: Digital resource that is also known as 'MyLabs' or 'MyLabs and tutoring'. The main source of exercises at University Beta. Includes computer aided assessment and features such as generating similar exercises and giving step-by-step solution methods. Also has a textbook feature, directing to the digital version of the textbook at University Beta. MyMathLabs is the resource that Brage uses the most. Benjamin used it little throughout the year, but a lot when he prepared for exams.

Overview lecture: At University Charlie, the first lecture of a given week was a traditional lecture, giving an overview of the topic.

Parent: Amalie often asked her mother questions, or to check her work. Her mother had studied mathematics.

Pencil & paper: Used as a shorthand for writing equipment (also includes the use of pens).

Phone: Mentioned by Brage as something he occasionally used in order to ask questions to fellow students.

Plenary: A session at the end of the week at University Charlie, where university staff shows how to solve some of that week's recommended exercises. The sessions were also video-recorded.

Previous exam sets: Each of the universities provided students with exam problems from previous years, as well as solution suggestions for said problems. The students used them a lot when preparing for exams.

Recommended exercises: The course organizers at universities Alpha and Charlie provided students with recommendations for which exercises to do. At

University Charlie, these were referred to as recommended exercises, while they were usually called homework at University Alpha.

Ring folder: Used by Adrian to organize his notes from lectures in various courses.

Rottmann's formula collection: Formula collection not made specifically for any university in the project. The only formula collection that a student (Adrian) mentioned by name.

Textbook: Each course has a textbook, each of them written in English. No course organizer calls the textbook a necessity, nor give the impression that students use it a lot.

Screenshots: Brage took screenshots with his laptop in order to store solution methods for specific problems in MyMathLabs.

Simulations: Benjamin used simulations as a resource category. Judging by the resources provided in the course or otherwise mentioned, he probably used simulations within SimReal, Wolfram Alpha or both.

SimReal: Web page containing simulation resources (URL: http://grimstad.uia.no/perhh/phh/matric/simreal/no/sim.htm). Mentioned by Bjørnsen as one of the resources students were made aware of. Not mentioned specifically by any student participant, but Benjamin categorically mentioned using simulations.

Sinus website: Website for the 'Sinus' textbooks for Norwegian upper secondary courses (URL: https://sinus.cappelendamm.no/) Includes videos on the topics covered. Mentioned by Bjørnsen as one of the resources students were made aware of. Not mentioned by any student participant.

Snacks: Christian filled in the exam as a study session in the Studert app and filled in snacks as a resource.

Solution suggestion: An example of a solution method for a given problem. For instance, previous exam sets came with solution suggestions.

Student assistants: At the math lab's at University Charlie, student assistants helped students with mathematical problems.

Studert app: The questionnaire app developed for the project. Brage used it as a resource to check how much he worked on mathematics each week and compare it to the lecturer's recommendations.

Video lectures: Videos that are not recorded lectures, but rather videos created by the lecturer to cover a mathematical topic in a way similar to a lecture, but often briefer and more to the point. They are called *videoforelesning* (literal translation: video lecture) at University Beta. University Charlie also provide video lectures.

Videos: On occasion, used as a resource category by students who both watched video lectures and YouTube videos.

Windows & marker: Christian wrote on his windows when he anticipated that a task would require a long solution and he may have to correct minor mistakes along the way.

Wolfram Alpha: Website (https://www.wolframalpha.com/) and applications for smart phones and tablets. Includes various functionalities for calculation, simulation and mathematical representations for various uses within and beyond the STEM fields.

YouTube: Platform for a wide variety of videos, with search functionalities. Most students at universities Beta and Charlie used it as one of their resources for finding explanations.

Appendix K: All schematic representations of resource systems

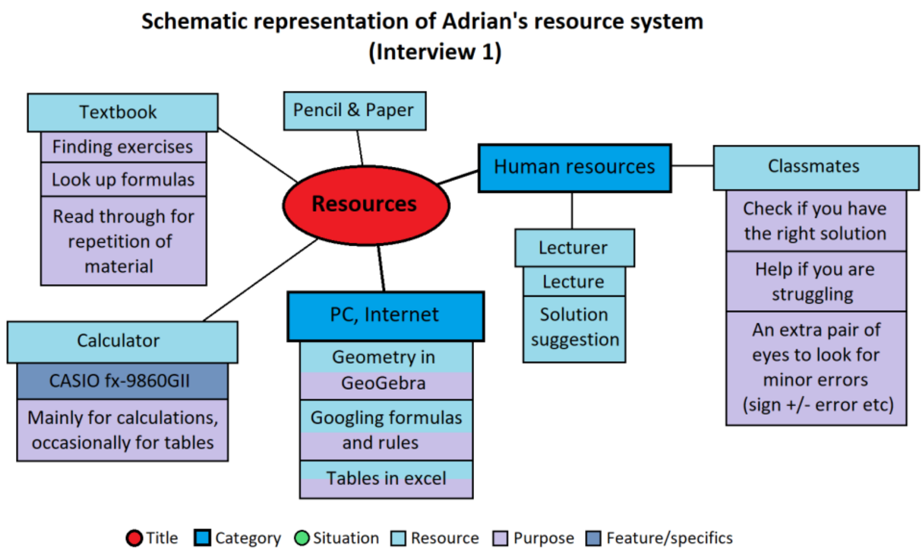

Figure K.1: The schematic representation of Adrian's resource system based on the mind map he constructed during the first interview session. He did not make changes to his mind map during the second interview.

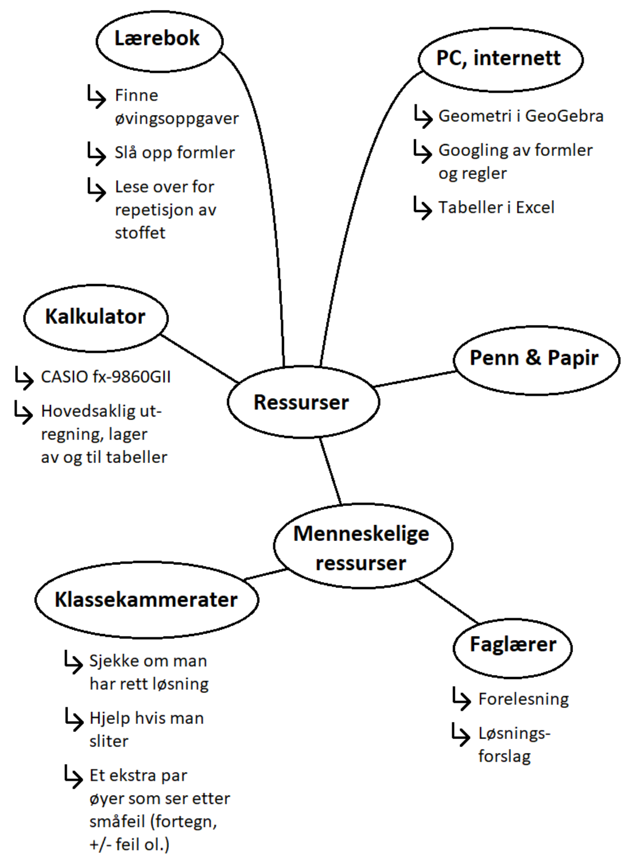

Figure K.2: Digital representation of the mind map Adrian constructed during the first interview.

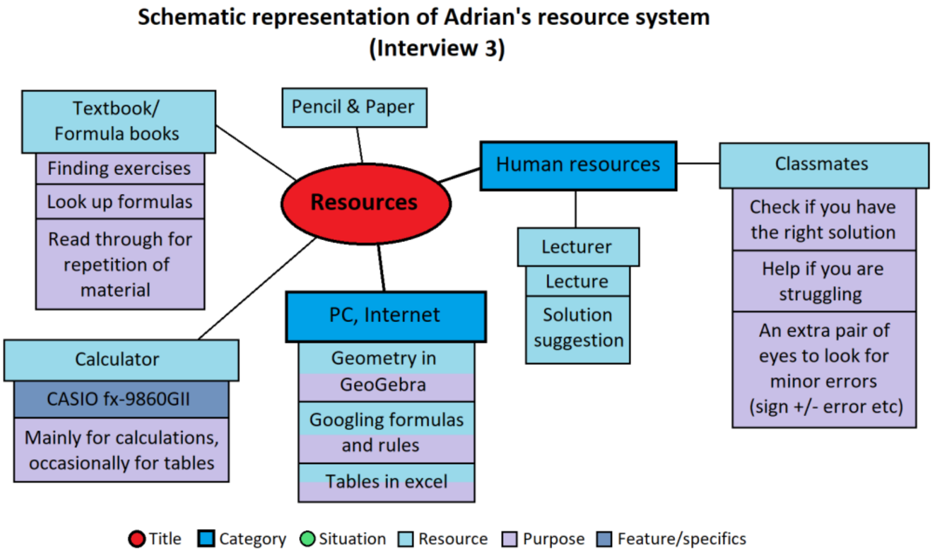

Figure K.3: The schematic representation of Adrian's resource system based on his mind map after he made changes during the third interview.

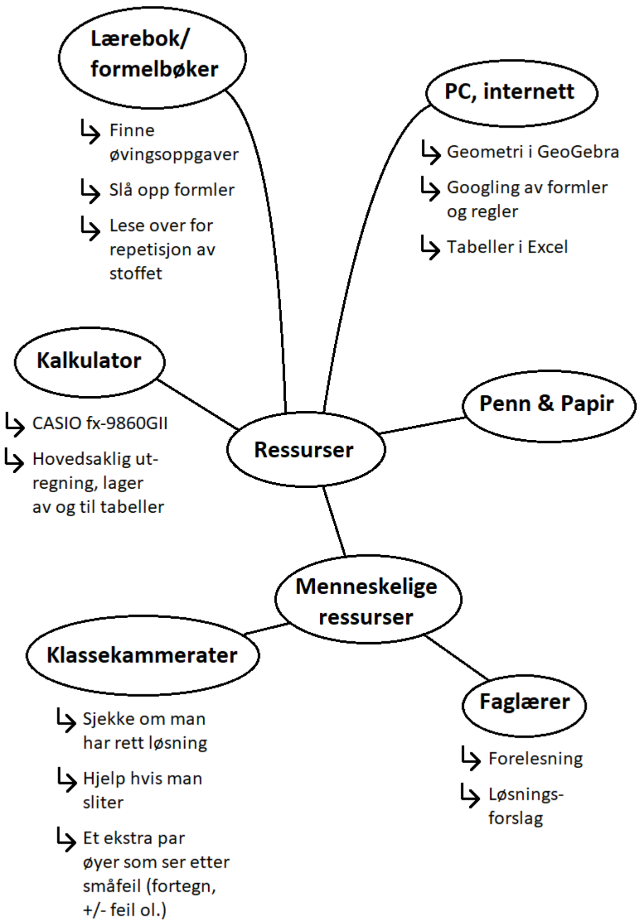

Figure K.4: Digital representation of the mind map Adrian constructed during the third interview.

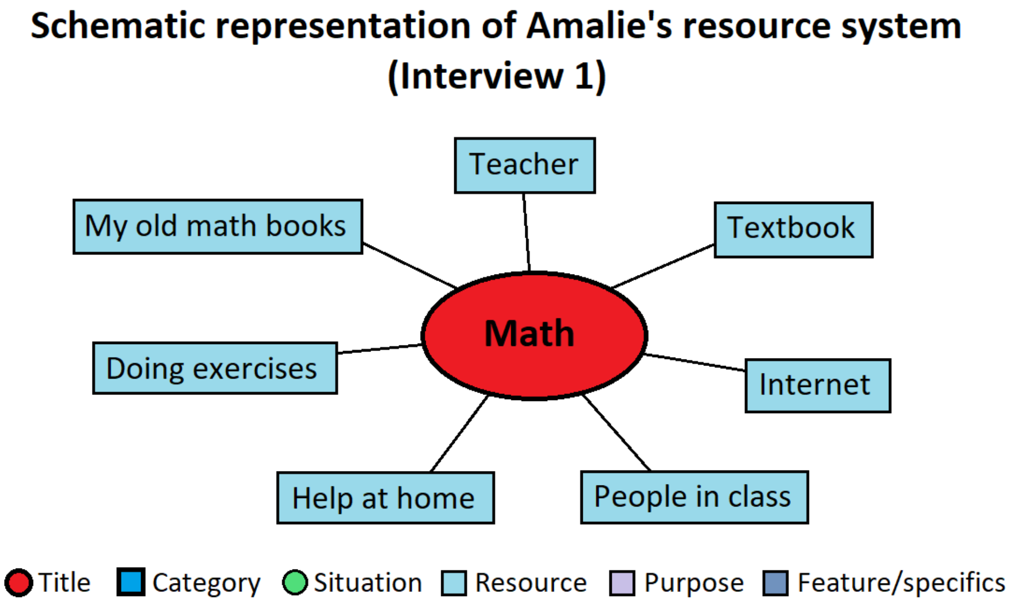

Figure K.5: The schematic representation of Amalie's resource system based on the mind map she constructed during the first interview session. One interview with her was cancelled. She did not make changes to her mind map during the last interview.

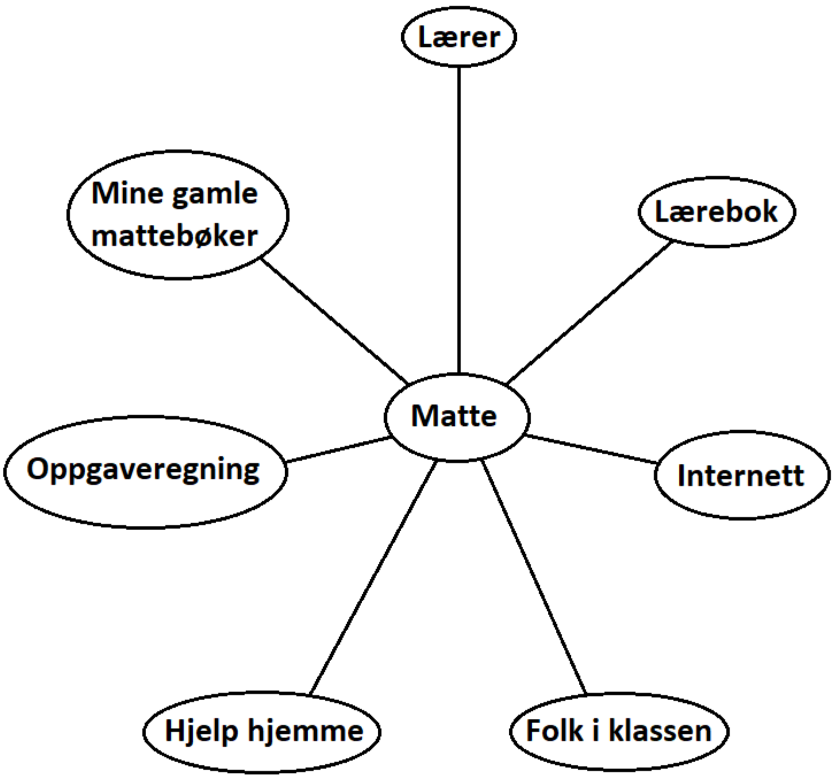

Figure K.6: Digital representation of the mind map Amalie constructed during the first interview.

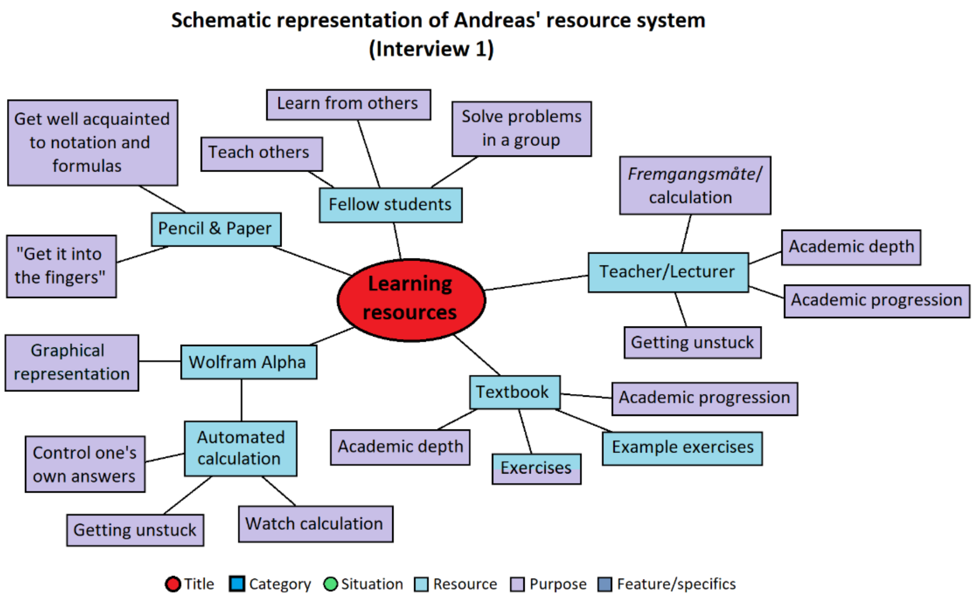

Figure K.7: The schematic representation of Andreas' resource system based on the mind map he constructed during the first interview session.

Figure K.8: Digital representation of the mind map Andreas constructed during the first interview.

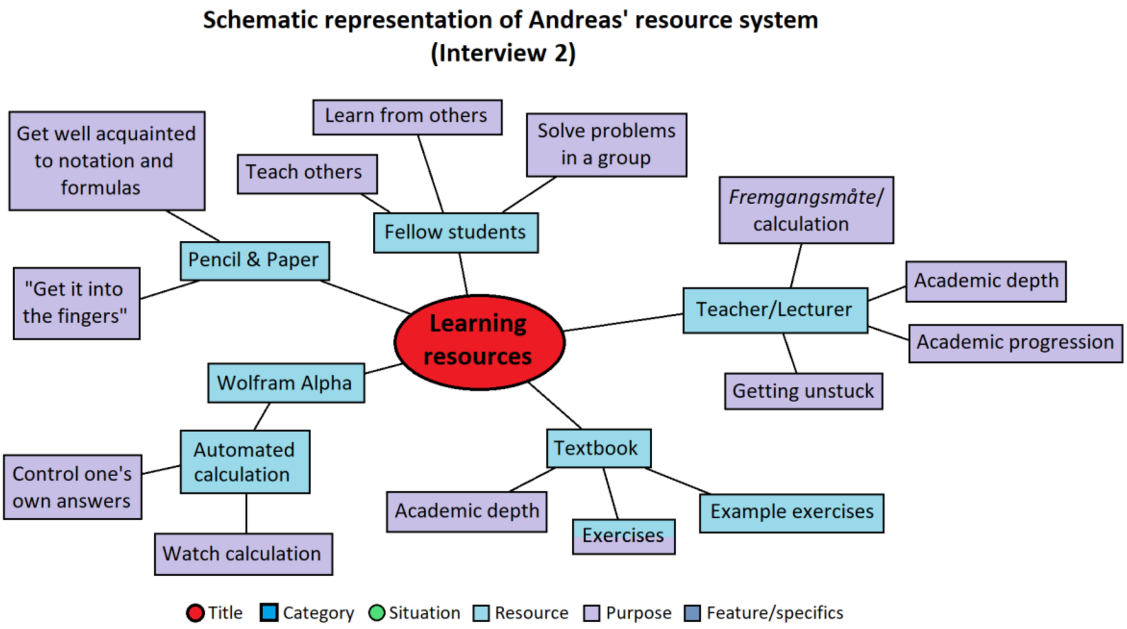

Figure K.9: The schematic representation of Andreas' resource system based on his mind map after he made changes during the second interview. He did not make changes to his mind map during the third interview.

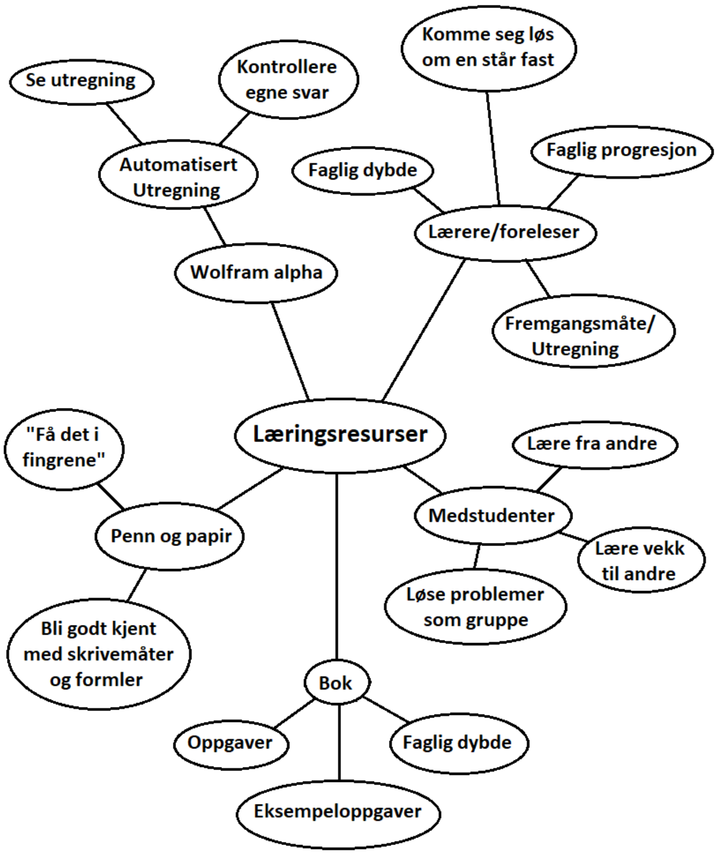

Figure K.10: Digital representation of the mind map Andreas constructed during the third interview.

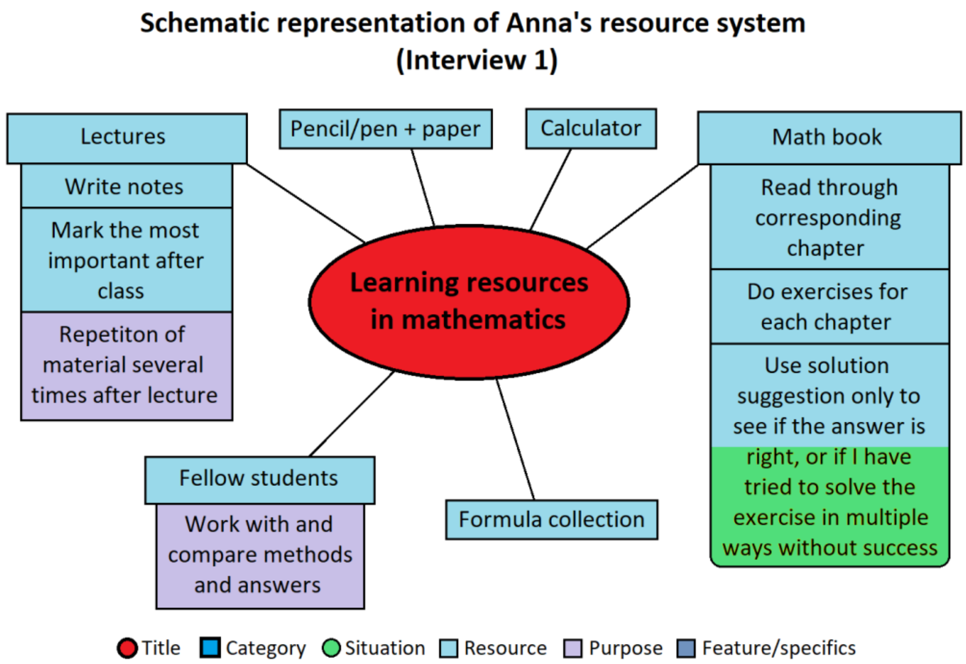

Figure K.11: The schematic representation of Anna's resource system based on the mind map she constructed during the first interview session. She did not make changes to her mind map during the third interview.

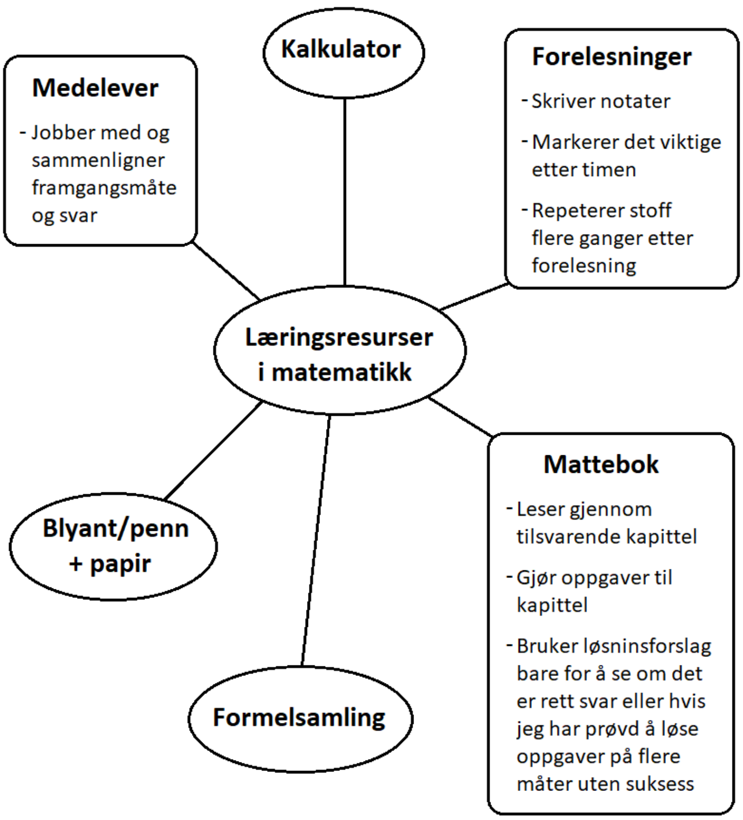

Figure K.12: Digital representation of the mind map Anna constructed during the first interview.

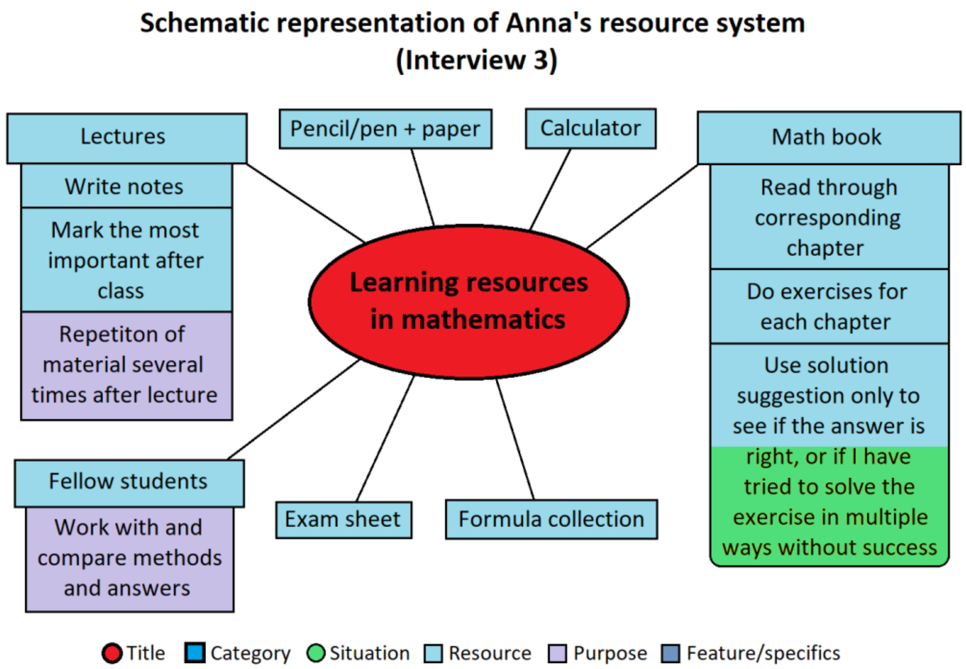

Figure K.13: The schematic representation of Anna's resource system based on her mind map after she made changes during the third interview.

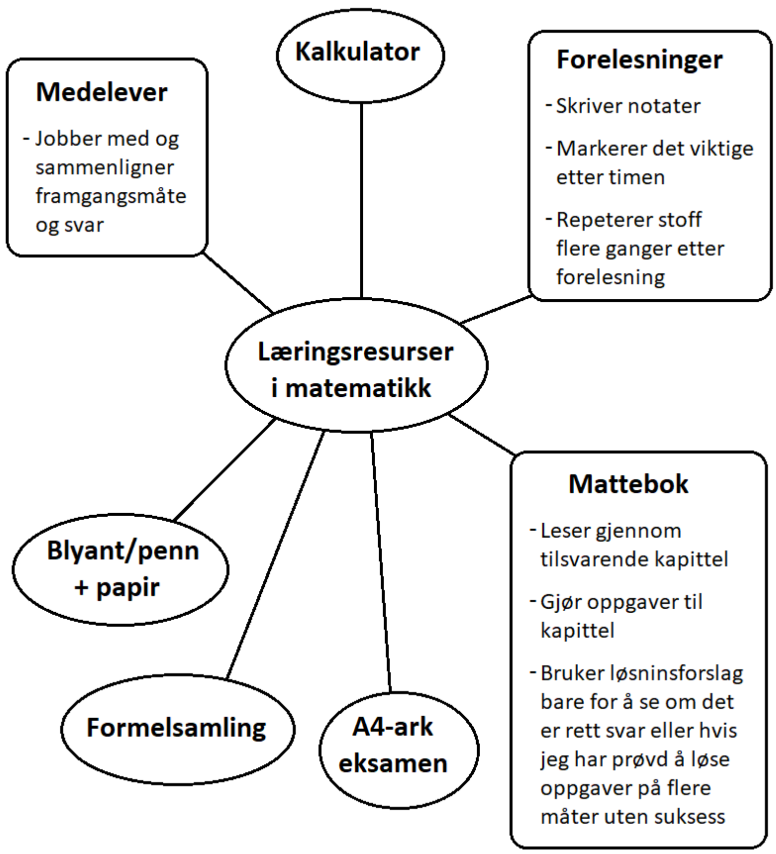

Figure K.14: Digital representation of the mind map Anna constructed during the third interview.

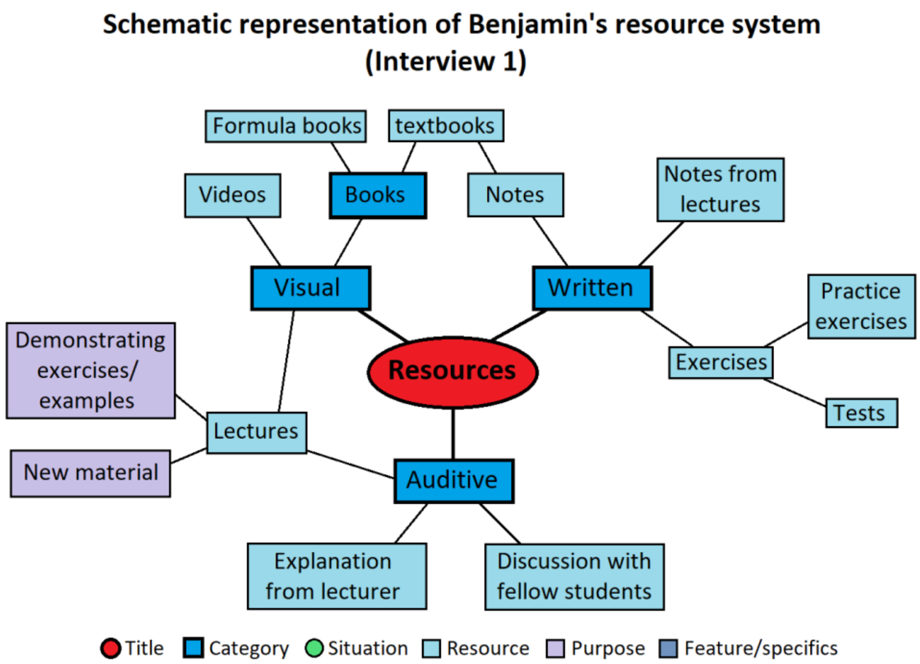

Figure K.15: The schematic representation of Benjamin's resource system based on the mind map he constructed during the first interview session.

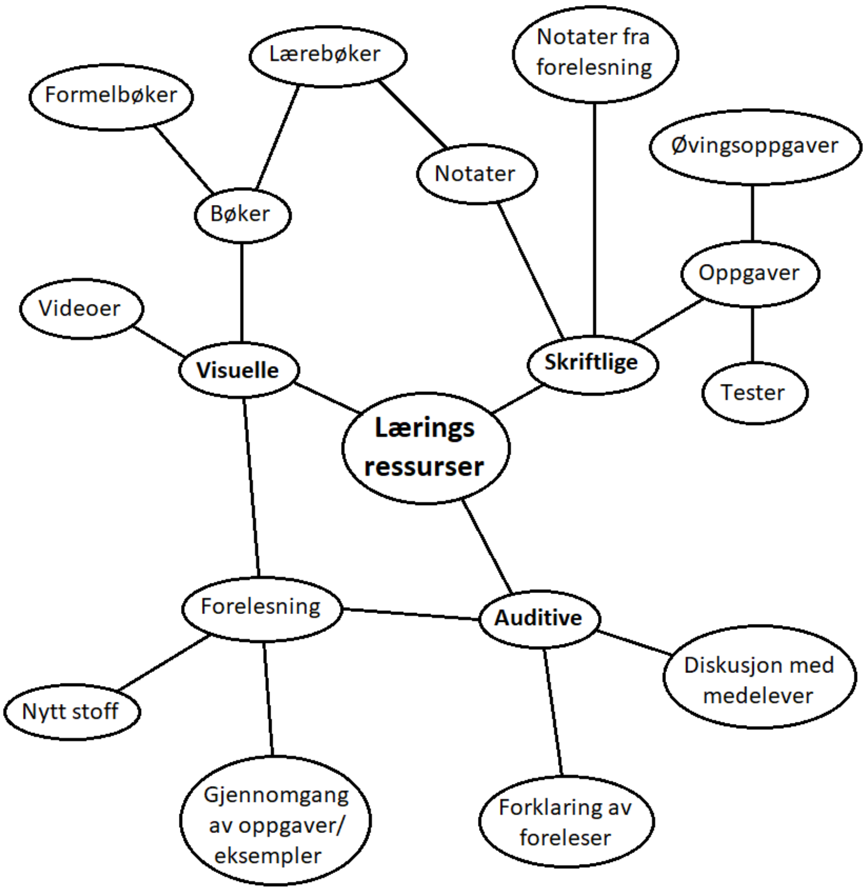

Figure K.16: Digital representation of the mind map Benjamin constructed during the first interview.

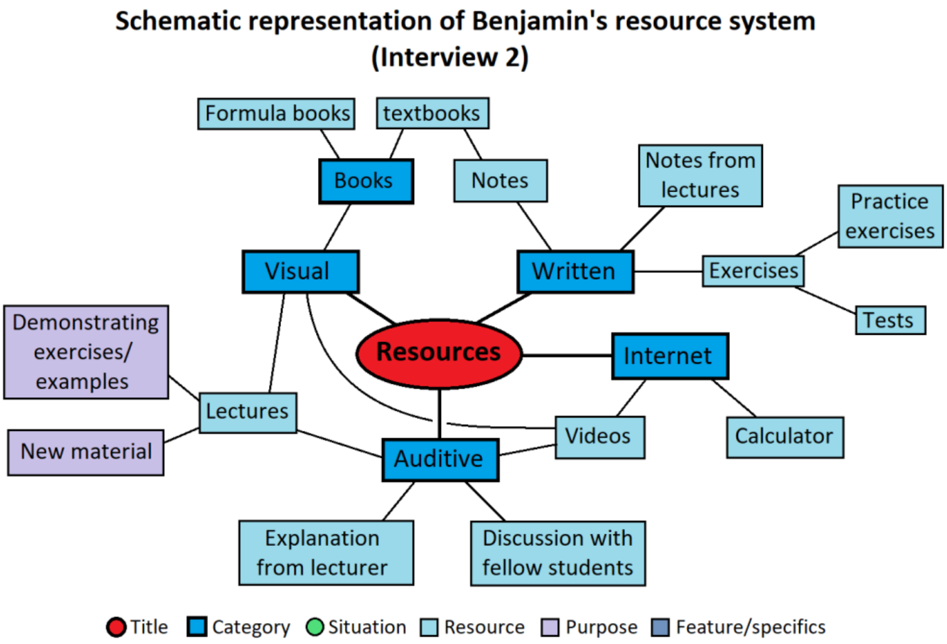

Figure K.17: The schematic representation of Benjamin's resource system based on his mind map after he made changes during the second interview.

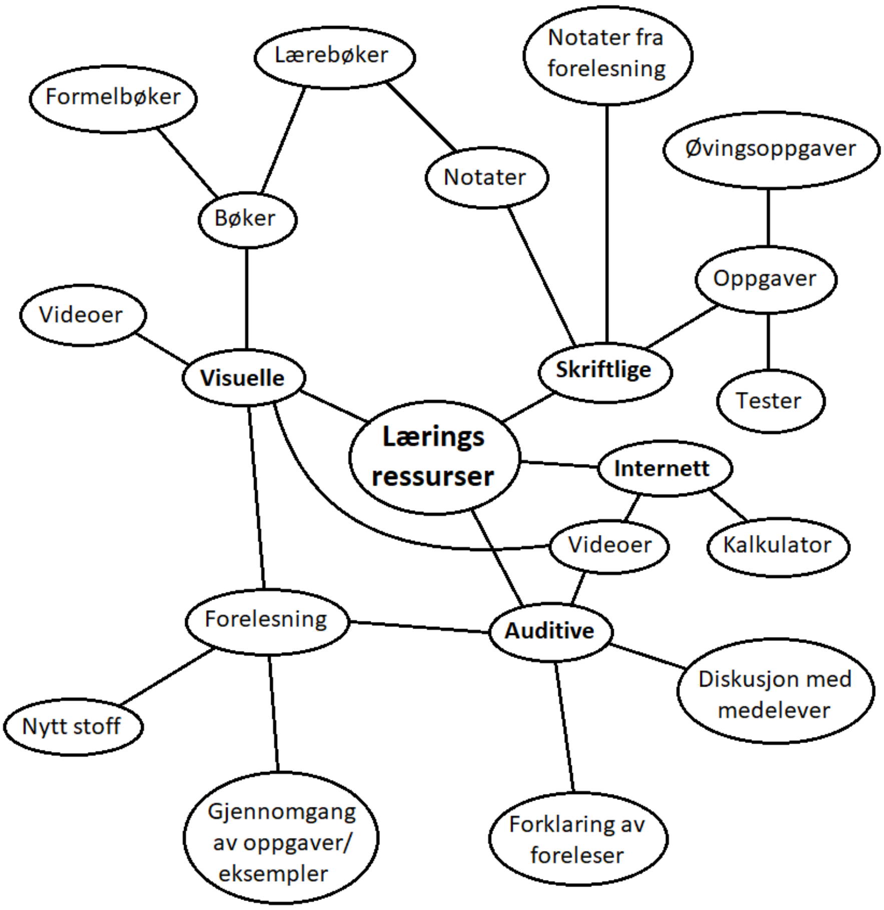

Figure K.18: Digital representation of the mind map Benjamin constructed during the second interview.

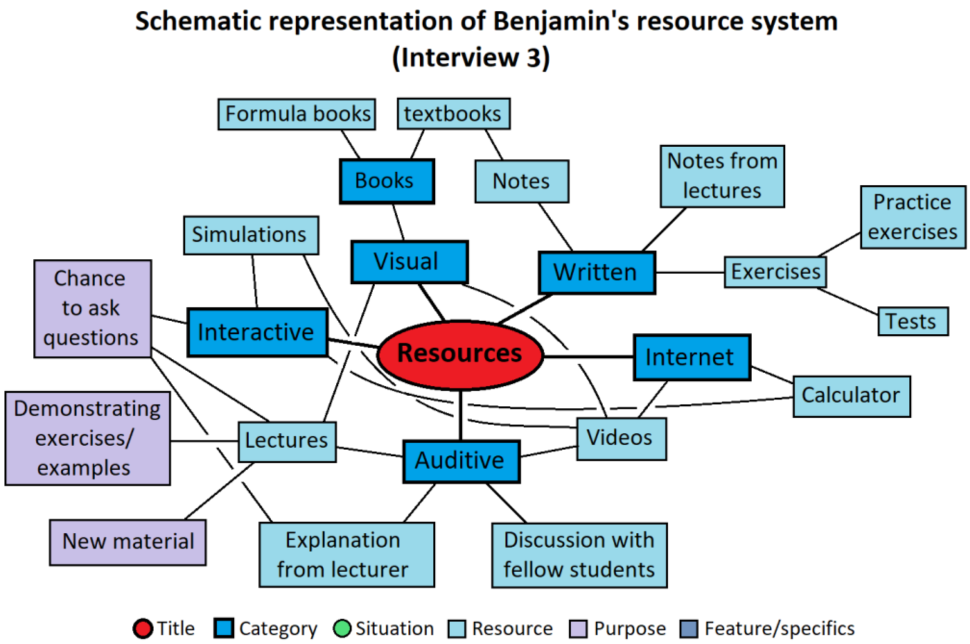

Figure K.19: The schematic representation of Benjamin's resource system based on his mind map after he made changes during the third interview.

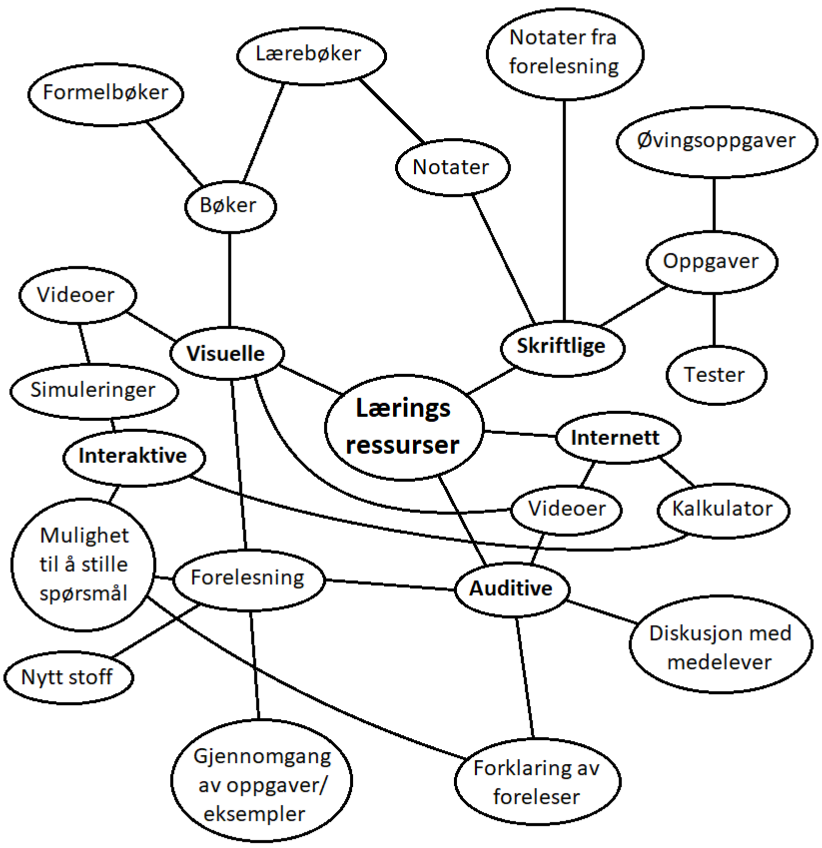

Figure K.20: Digital representation of the mind map Benjamin constructed during the third interview.

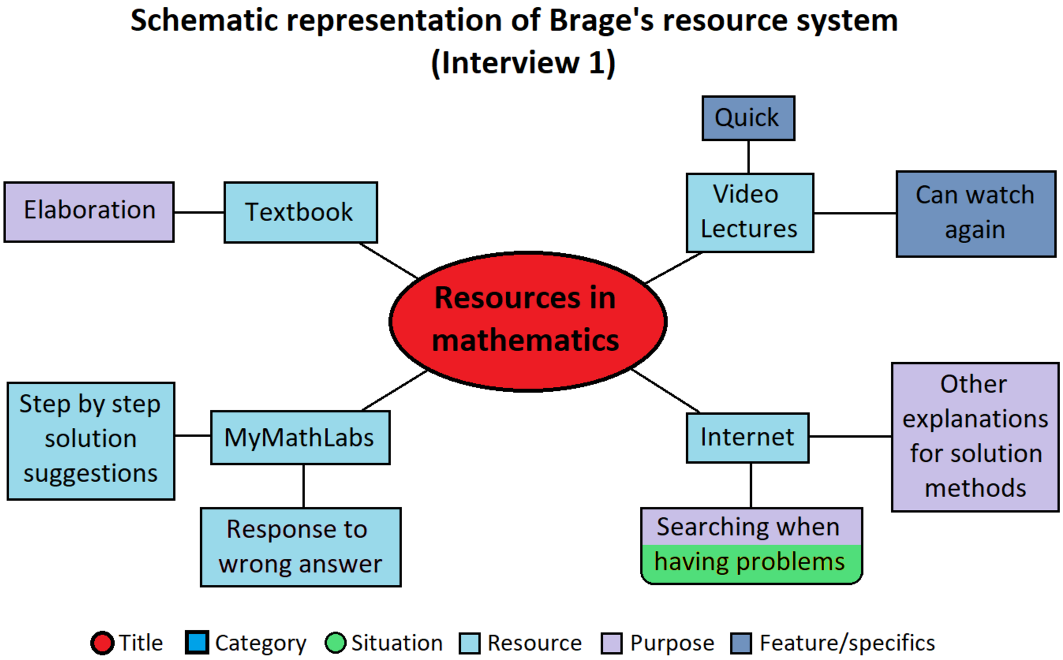

Figure K.21: The schematic representation of Brage's resource system based on the mind map he constructed during the first interview session.

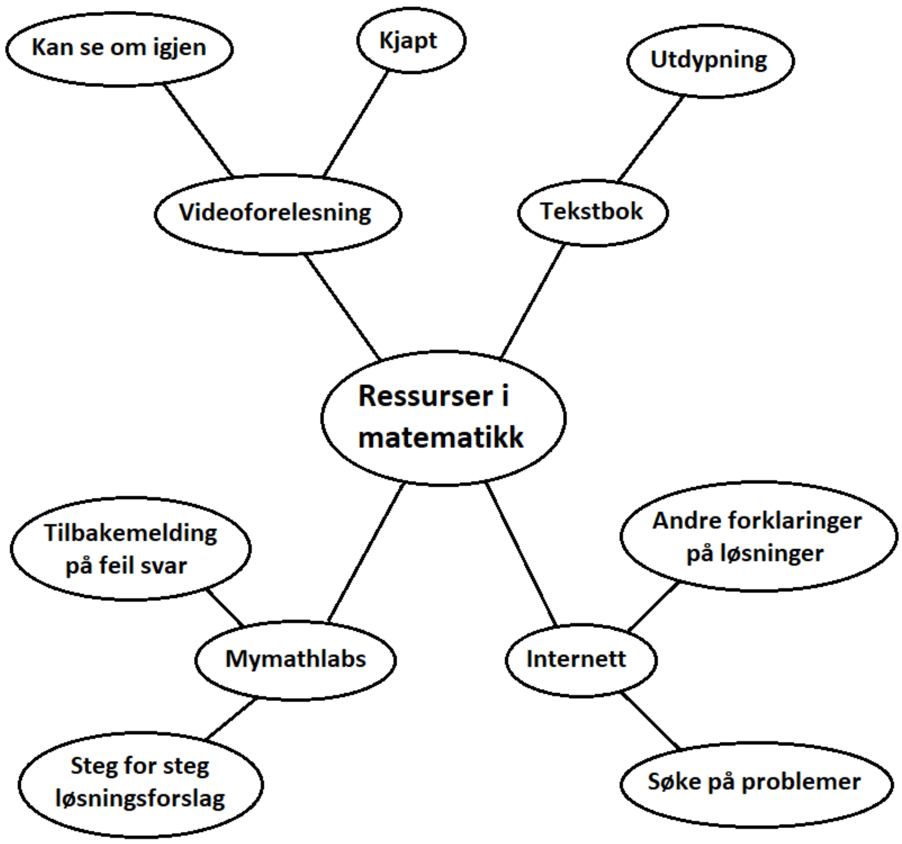

Figure K.22: Digital representation of the mind map Brage constructed during the first interview.

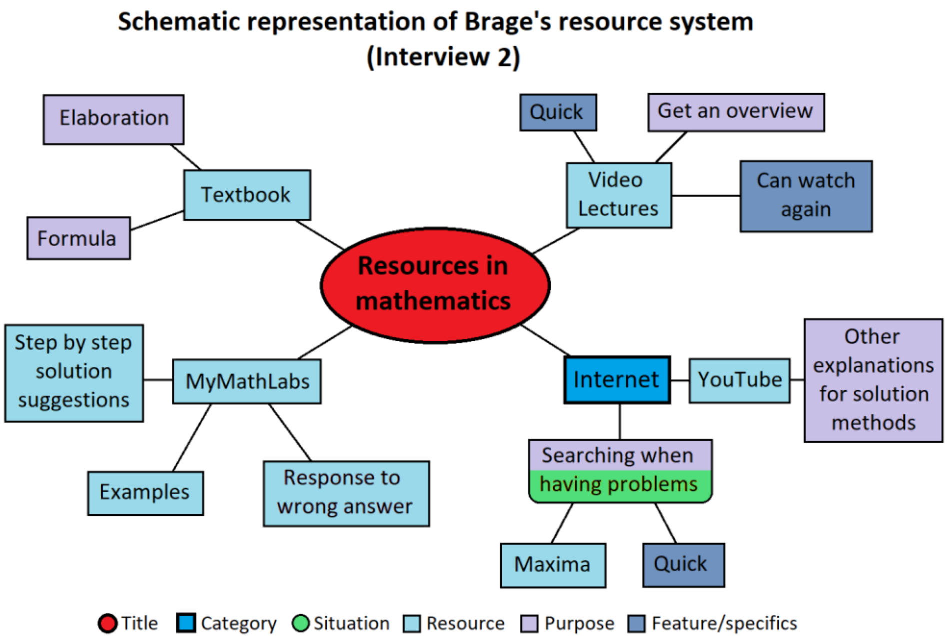

Figure K.23: The schematic representation of Brage's resource system based on his mind map after he made changes during the second interview. He did not make changes to his mind map during the third interview.

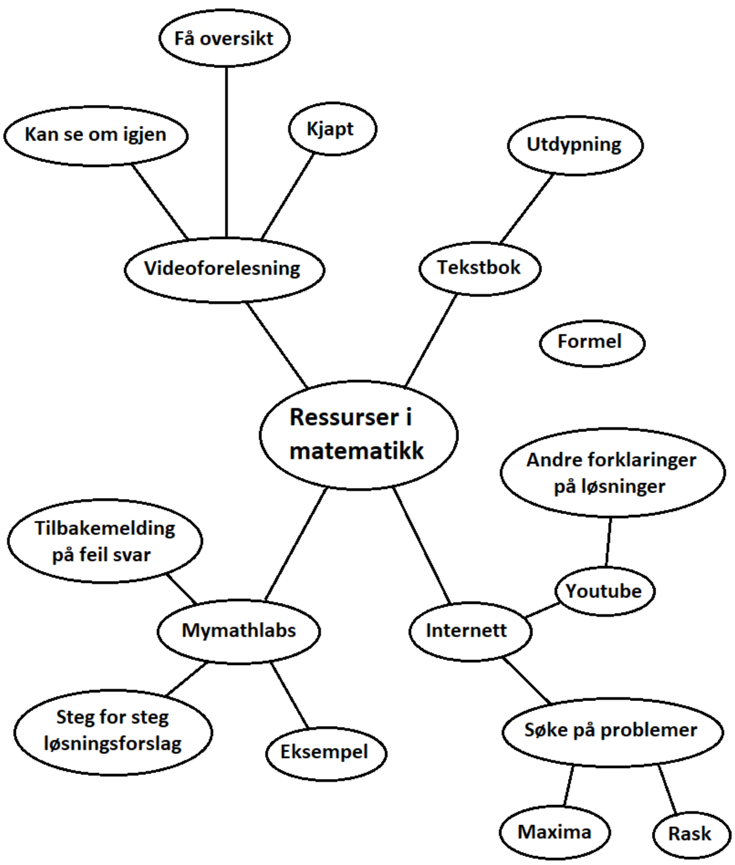

Figure K.24: Digital representation of the mind map Brage constructed during the second interview.

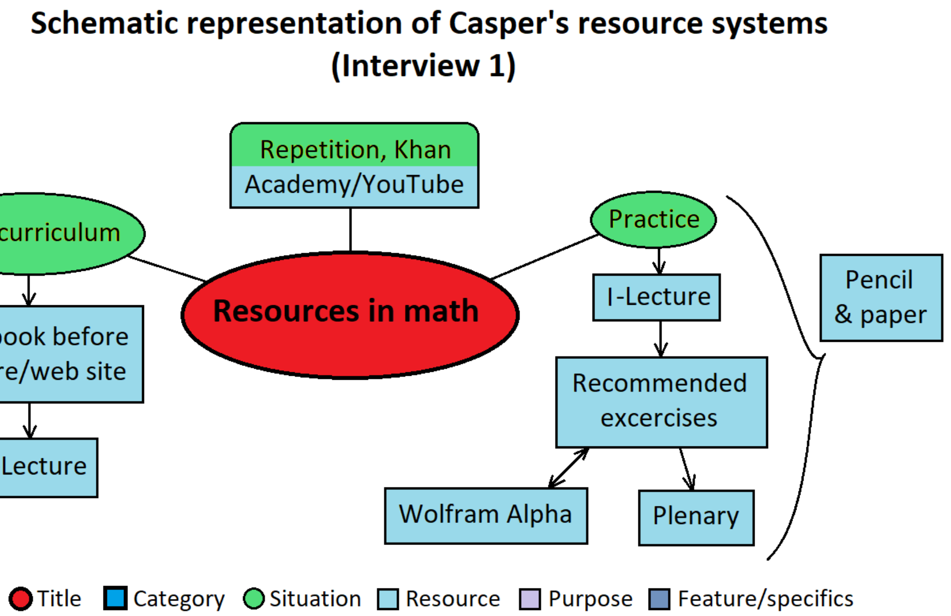

Figure K.25: The schematic representation of Casper's resource system based on the mind map he constructed during the first interview session. He did not make any changes to his mind map during the second or the third interview.

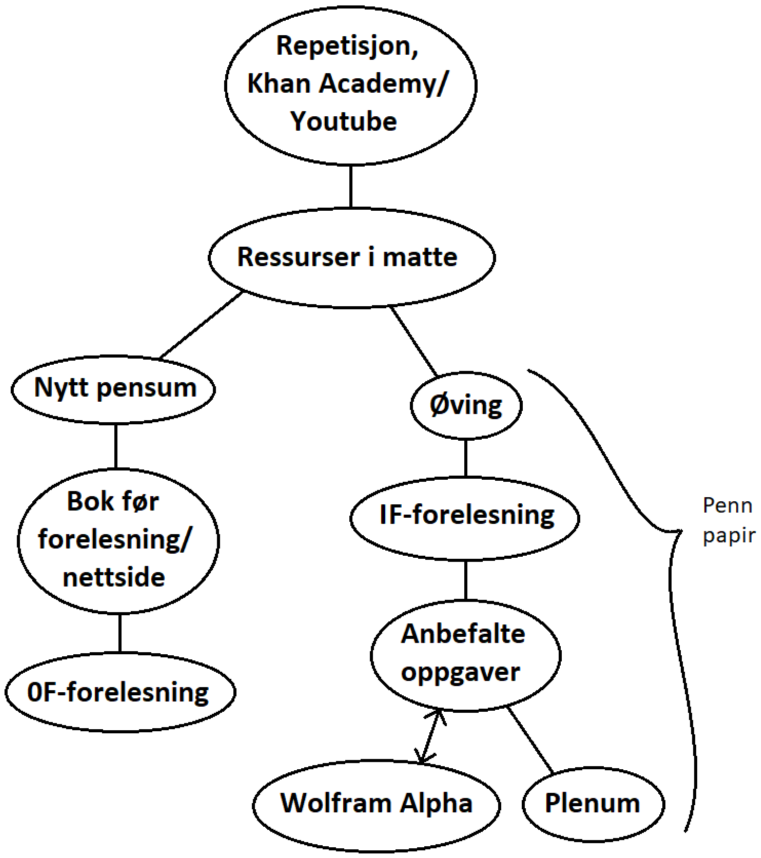

Figure K.26: Digital representation of the mind map Casper constructed during the first interview.

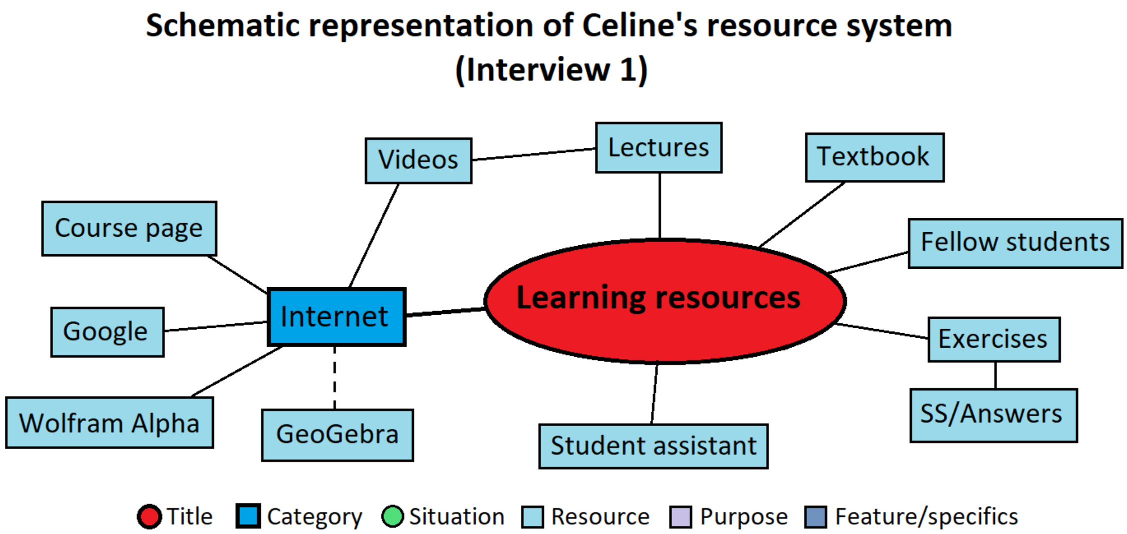

Figure K.27: The schematic representation of Celine's resource system based on the mind map she constructed during the first interview session. She did not make any changes to his mind map during the second or the third interview.

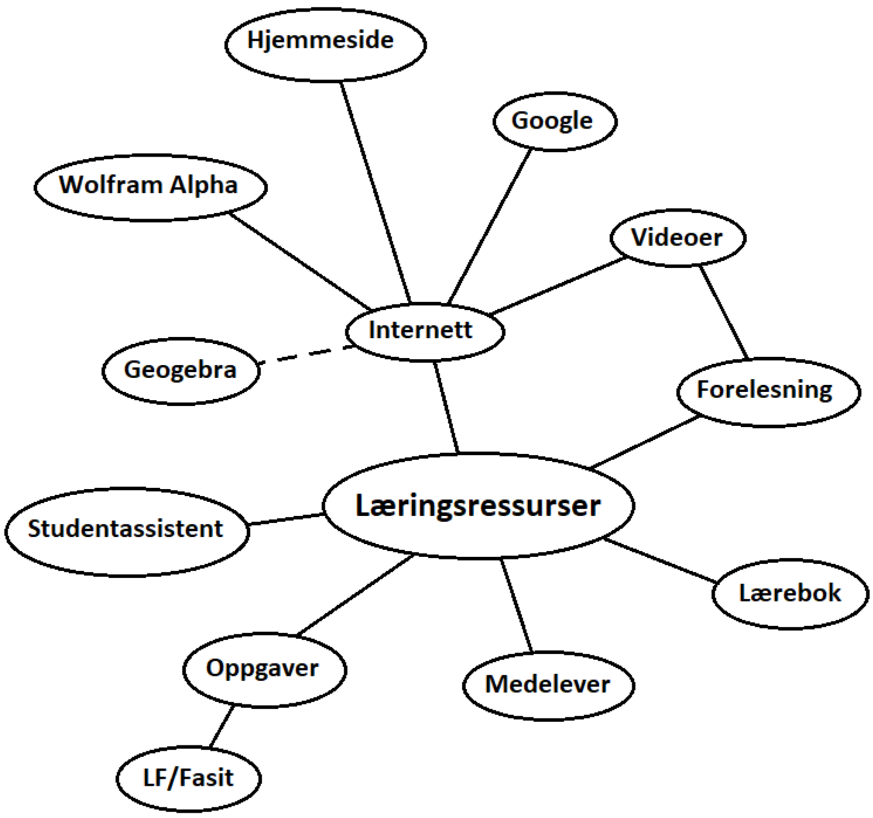

Figure K.28: Digital representation of the mind map Celine constructed during the first interview.

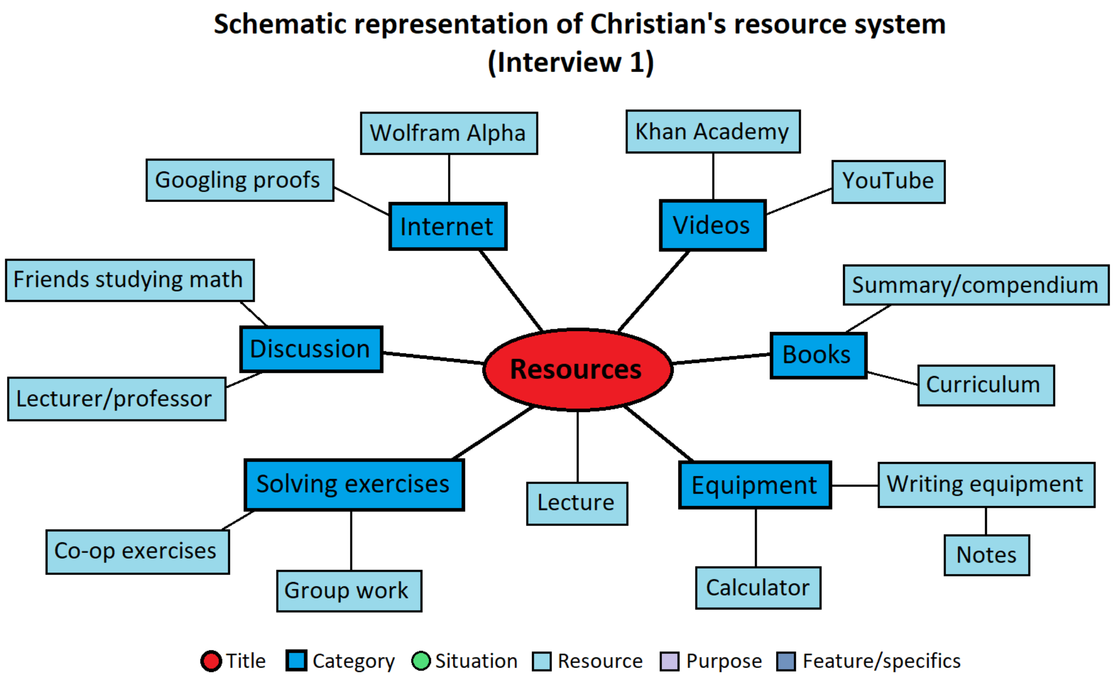

Figure K.29: The schematic representation of Christian's resource system based on the mind map he constructed during the first interview session.

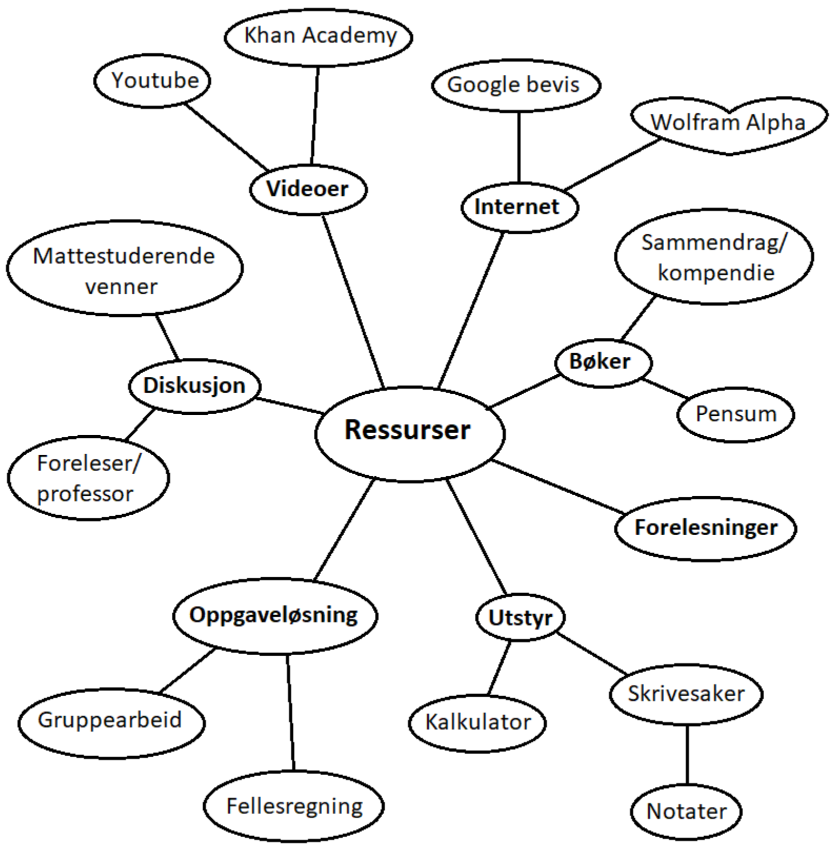

Figure K.30: Digital representation of the mind map Christian constructed during the first interview.

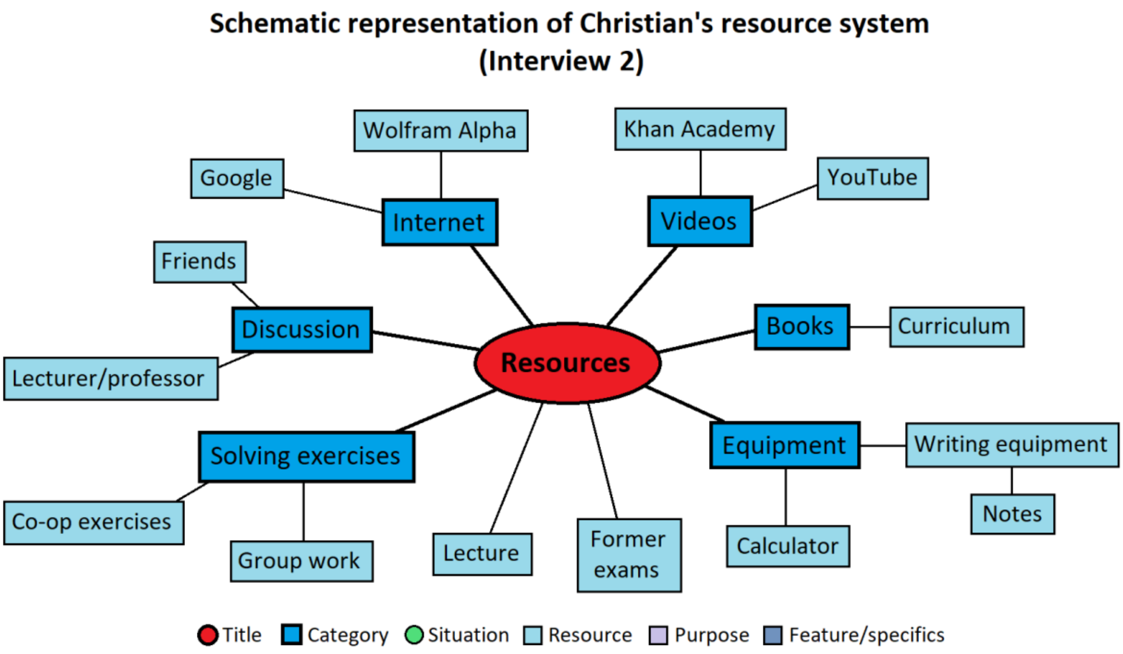

Figure K.31: The schematic representation of Christian's resource system based on his mind map after he made changes during the second interview.

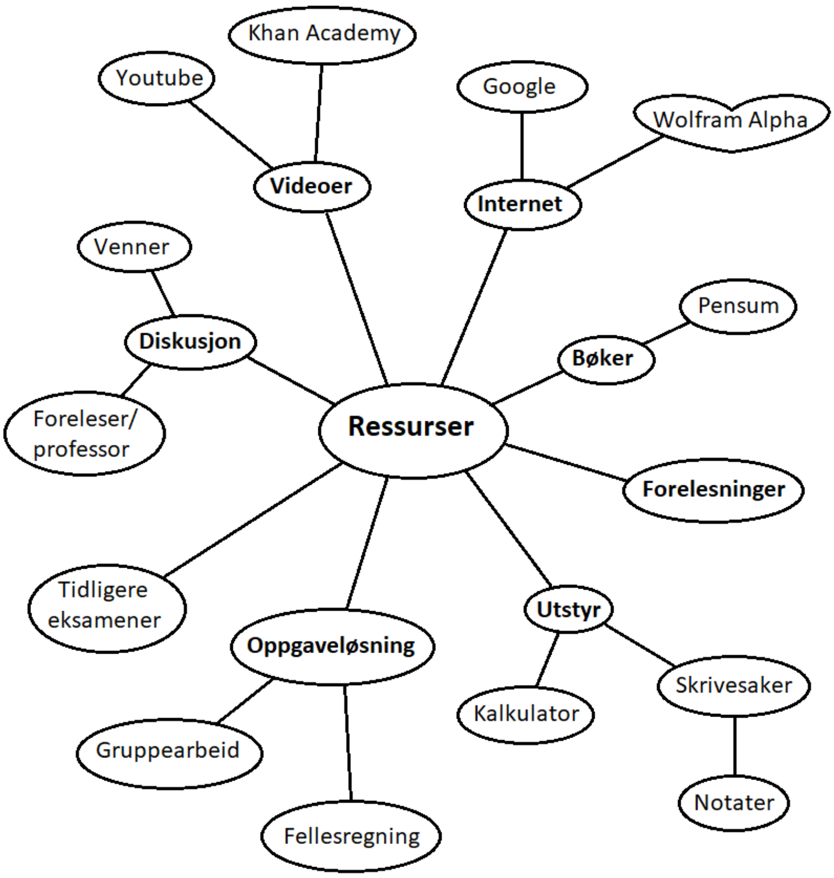

Figure K.32: Digital representation of the mind map Christian constructed during the second interview.

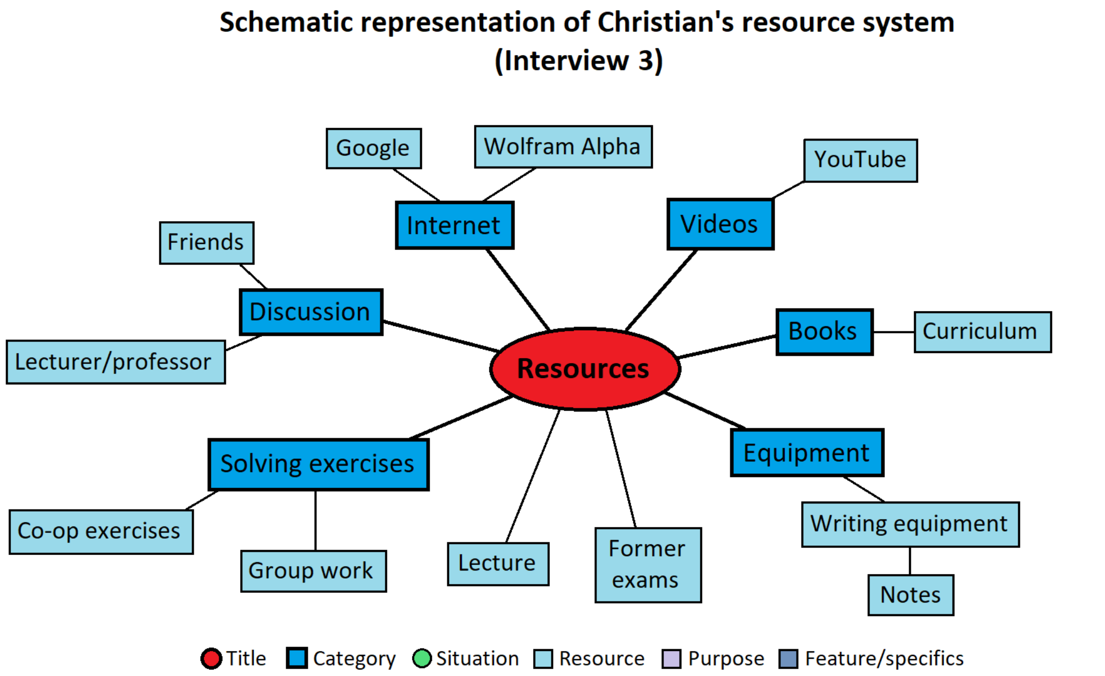

Figure K.33: The schematic representation of Christian's resource system based on his mind map after he made changes during the third interview.

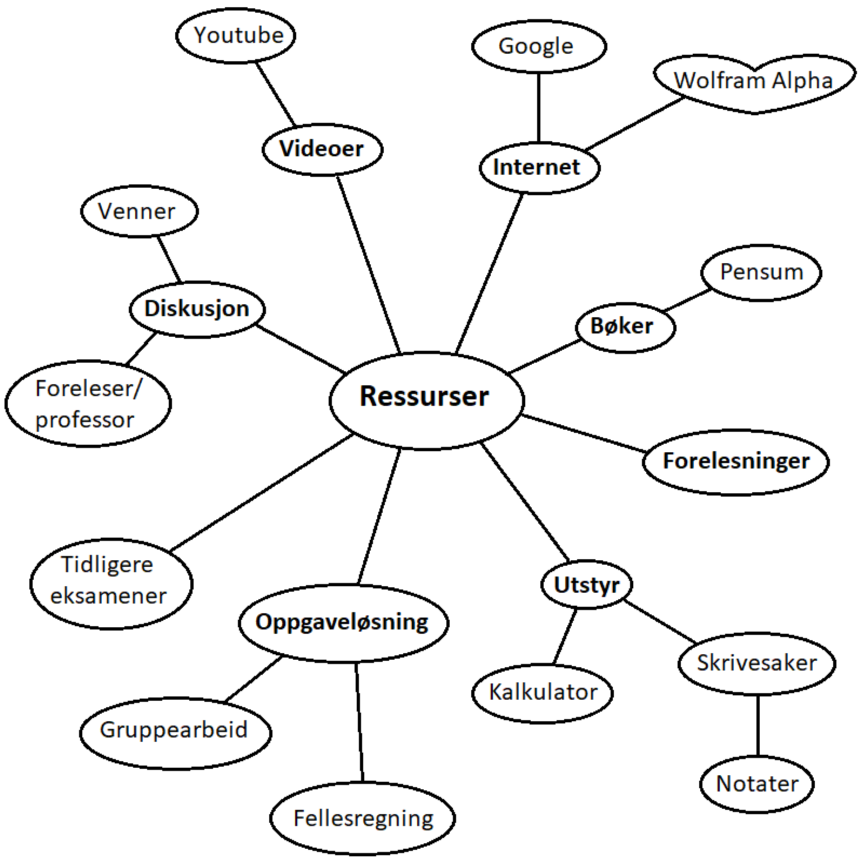

Figure K.34: Digital representation of the mind map Christian constructed during the third interview.

Appendix L: All identified themes and results

Included in table L.1 is the entire system of theme categories, themes, subthemes and results from the thematic analysis within the project.

Theme category	**Theme/result**	**Subtheme/result**
Classes of situations	1.1 Exam preparation	1.1.1 Emulating the exam situation
	1.2 Experienced difficulty	1.2.1 Ease leads to use of emphasized resources
		1.2.2 Difficulty leads to use of people
	1.3 Working with fellow students	1.3.1 Working with others leads to use of text resources and discussion over digital resources
	1.a Degree of familiarity	
	1.b Lack of time	
	1.c Priority of others	
	1.d Areas of mathematics	
	1.e Working with mandatory assignments	
Schemes of utilization	2.1 Variety of strategies for working alone	2.1.1 Strategies concern a variety of resources
		2.1.2 Variety of strategies for taking or using notes
	2.2 Variety of strategies for working with others	2.2.1 Generally, groups of three or four are the most common
		2.2.2 Extent of working with others compared to alone varied
Evolution of documents	3.1 High stability of documents	
	3.2 High degree of changes through adaption	
	3.3 Low degree of changes through reflection	

Didactical resource purposes	4.1 Introduction	4.1.1 Emphasized resources used for introduction
	4.2 Practice	4.2.1 Variety of resources used for practice
		4.2.2 Exercises considered important
	4.3 Evaluation	4.3.1 Three main strategies for checking answers
		4.3.2 Appreciation for every option in the assessment hypothetical
		4.3.a Some general evaluation
	4.4 Explanation	4.4.1 Variety of resources used for explanation
		4.4.2 Appreciation for additional explanation
		4.4.3 Meta-resources used to find utilization resources
Resource decisions	5.1 Primarily goal-based decisions	5.1.1 Emphasized resources used before non-emphasized resources
		5.1.a Fellow students used before the lecturer
	5.2 Decisions are partially preference-based	5.2.2 Not much appreciation for the textbook
		5.2.a Unfamiliar digital resources not appreciated
Resource discovery	6.1 Discovery through current education	
	6.2 Discovered through previous education	
	6.a Wolfram Alpha recommended by fellow students	

Quality criteria	7.1 Simplicity	
	7.2 Efficiency	
	7.a Control of the pace	
	7.b Quality of explanations	
	7.c Breadth of functionalities	
	7.d Price	
Other results	8.1 Mathematics is a low priority when students are short on time	8.1.1 Taking a break from mathematics when preparing for other exams
	8.a Focus on understanding	

Table L.1: All the theme categories, themes, sub-themes and results identified through thematic analysis. Results may be tied to a theme category and listed in the theme column or tied to a theme and listed in the subtheme column. They are enumerated with a letter at the end rather than a number.