Høgskulen på Vestlandet

MASTER’S THESIS

Studying the impact flipped classroom teaching has on conceptual knowledge development in primary school science

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Abstract

In this experimental case study, I compared how the flipped classroom method and the traditional classroom method could impact primary school students' development of conceptual knowledge in science education. The study took place in one 5th-grade class (n = 11) and three different 7th-grade classes (n = 32) from different schools in Norway. The 5th-grade class participated in a pilot that was conducted to further develop the design, leaving the 7th-grade classes for the main study. Here one class used the flipped classroom method, and two classes used the traditional classroom method.

The teaching was designed to split the lesson into an introductory part and an activity part, with the introduction being the difference between the respective teaching methods. During and after participating in the introduction and the activity, all students were asked to fill out a questionnaire and to create a mind map respectively, depicting the knowledge gained in the lessons, which was then collected for analysis.

The mind maps were analysed using D'Antoni's Mind Map Analysis Rubric (MMAR), and the results showed that the developed conceptual knowledge of the students had no significant difference between the two teaching methods. As the sample size was relatively small, the case was analysed further using questionnaire answers. From the difference in lesson designs between the teaching methods, the findings could imply that the flipped classroom performed better in this experiment, as the traditional classroom was given more time to learn the same content, without achieving a significantly better performance.

Keywords: Flipped classroom, conceptual knowledge, practical work, homework, primary school, science education

Samandrag

I denne eksperimentelle kasusstudien har eg samanlikna korleis omvendt undervisning og tradisjonell undervisning kunne påverke grunnskuleelevar si utvikling av deira forståing for konsept i naturfag. Studien vart teke føre seg i ein klasse på 5. trinn (n = 11) og tre klassar på 7. trinn (n = 32) frå ulike skular i Noreg. Klassen på 5. trinn deltok i ein pilot-gjennomgang, som vart gjennomført slik at designet på studien kunne vidareutviklast, medan klassane på 7. trinn deltok i hovudstiden. Her brukte ein klasse omvendt undervisning, medan to klassar brukte tradisjonell undervisning.

Undervisningsopplegget vart delt inn i ein introduksjonsdel og ein aktivitetsdel, der introduksjonen vart den vesentlige forskjellen mellom dei respektive undervisningsformane. Under og etter gjennomføringa av opplegget vart elevane spurt om å fylle ut eit spørjeskjema, og om å lage eit tankekart av det dei hadde lært gjennom opplegget, slik at desse kunne samlast inn som data etter gjennomgangen.

Tankekarta vart analysert ved hjelp av D'Antoni sitt kartleggingsverktøy for tankekart (MMAR), og resultata av analysen hadde ingen signifikant forskjell i elevane si forståing mellom dei to undervisningsmetodane. Ettersom studien hadde eit relativt lite utval av deltakarar, vart casen analysert vidare ved hjelp av svara frå spørjeskjema. Dersom ein ser på skilnadane i designet av undervisninga, kan funna tyde på at omvendt undervisning har prestert betre enn tradisjonell undervisning i dette tilfellet, ettersom elevane med tradisjonell undervisning hadde meir tid til å gå gjennom det same innhaldet, utan å vise til ei merkverdig auking i resultata.

Nøkkelord: Omvendt undervisning, konseptforsåing, praktisk arbeid, lekser, grunnskule, naturfag

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Finally, after five years of study, it seems my time as a student at HVL is over. Firstly, I would like to express a special thanks to my supervisor, Lydia S.H., for inspiring and supporting me with ideas and guidance throughout this project. I would also like to thank the different teachers and students that took time out of their schedules to participate in my project, as I would not have been able to conduct my research without them. I also want to thank my professors, and especially Idar M., for helping me with the creation of my consent form, as well as providing me with some feedback at the end of my project. Further, I want to thank those who have spent hours reading through the earlier versions of this document, looking for typos and other errors, as they have done a great job helping me clean up the mess that I sent to them. I also want to thank my family and friends, who encouraged me to keep my head up, even on the hardest of days. Finally, I want to express how much I have appreciated working alongside my fellow students, who have provided me with a lot of valuable feedback, and who have been great company during our lunch and dinner breaks at school.

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1 Introduction

The classroom is always evolving, with new teaching methods, values, and ways of incorporating the students' everyday experiences into their teaching. A big part of our school system is the homework that is assigned to the students, and how this is carried out is a topic that has been discussed for a long time in Norwegian politics, as well as in other places in the world (Jerrim et al., 2019; Pham, 2010; Utdanningsdirektoratet, 2021). Different sides argue whether the current homework-format is working, if it is something that should change, or if it should be replaced by something completely different, such as longer school days. At the same time, technology has also been evolving, and it is now a big part of our everyday lives. This also includes our children's and students' lives, and they are more familiar with technology than they have ever been before. As a new possible asset to the field of teaching, I have caught some interest in what this could mean for the education of my students in the future. I started wondering how the education system could use this technology to its full potential? And if there was some way to tackle the homework topic using said technology?

A teaching method that tries to utilize technological tools, and one that might be able to offer an alternative approach to homework, is the flipped classroom. This teaching method has mostly been used in higher education (Erbil & Kocabas, 2020, p. 3), but I believe it has some potential with the younger students in primary school as well, as they are also becoming increasingly familiar with using technology. Flipped classroom learning completely changes the design of homework, as it switches up what is done at home and what is done in class. When I first heard about this teaching method, it very quickly caught my interest, as my teacher had used a similar teaching format when I was in High School. At the time I did not know this teaching format had a name, but I knew that I enjoyed coming prepared to class, and having the teacher available while we were working on our tasks. As the flipped classroom has not yet seen an extensive use in primary school, I decided to study this specifically, as I believe it has a lot of potential when it comes to making science education more student-centred and oriented around doing activities and experiments (Nes, 2021). The chosen research questions for this study are therefore:

- How does the development of conceptual knowledge in primary school science compare between a flipped classroom and a traditional classroom?

- Which teaching method is more efficient in terms of time and effort?
- How could flipped classroom teaching be a possible solution to the homework debate?

1.1 Early interest in the flipped classroom

Before I started working on my master thesis, I performed a literature review in an FOU-thesis (Nes, 2021), where I got a deeper understanding of the flipped classroom, and what research had been previously made concerning this teaching method in primary school. Throughout this literature review, I was made aware of the lack of studies regarding the efficiency of flipped classroom learning in primary school science, and this became the common factor in the articles I studied. My Literature review was focused on four different studies that addressed flipped classroom teaching in primary school. I have created a table containing the purpose of each study, the methods they used to research their purpose, as well as the results and conclusions they found (Table 1).

Table 1: *Content of the main articles in my previous literature analysis (Nes, 2021, p. 7).*

Article	Županec et al., 2018	Erbil & Kocabas, 2020	Loizou & Lee, 2020	Askedal, 2016
Category	*Experimental*		*Case study*	
Purpose	Study efficiency and engagement in the flipped classroom. Measuring test results and mental effort.	Study the effect on academic achievement and motivation in flipped classroom learning and cooperative learning, separated and combined.	Find lacking research about the flipped classroom in primary education. Study how teachers, parents and students experience using flipped classroom.	Display students' experience of motivation towards homework presented as flipped classroom teaching.
Method	Serbia, 112 students, 2 groups in 7th grade (12-13 yrs.) from 2 schools, but with the same teacher. 1 control group, 1 experimental group. Experimental study with pre/post-test, 18 questions with multiple choice + 5-point Likert scale for their mental effort per question.	Turkey, 100 students, 4 groups in 4th grade from 2 schools. 3 experimental groups, 1 control group. Experimental study with pre/post-test, 47 questions with multiple choice to test academic achievement + 31 questions to test motivation.	Cyprus, 77 students, 5 groups between 8 – 11 yrs. from 5 schools. 48 parents. All groups were introduced to the flipped classroom. Multi-case study with observations and interviews. A flipped classroom model was created, which all groups used.	Norway, 49 students, 2 groups in 9th grade from 1 school with the same teacher. Both groups were introduced to the flipped classroom. Instrumental case study with questionnaire to find a strategical sample, semi-structured interview with this chosen sample.
Findings	Positive changes to test results, and less mental effort required to complete the tasks. More engaged in the classroom.	Noticeably positive effect with both flipped classroom learning and cooperative learning in both academic achievement and motivation.	Teachers, parents, and students were mostly positive to the change. Some parents were critical.	Positive feedback to flipped classroom learning. Many students usually did homework to avoid a warning, but this changed when the homework had a purpose.

In designing this study, I produced a recreation of two existing studies combined. I chose to do a recreational study, as this would provide me with tested and tried design components that could further support the reliability of my results. The two studies I recreated and combined included; "Determination of educational efficiency and students' involvement in the flipped biology classroom in primary school" (Županec et al., 2018), which was a part of my literature analysis above, and "Development of a scoring system to assess mind maps" (Evrekli et al., 2010).

Županec's study used two different student groups with the same teacher, to study the effect of flipped classroom teaching by measuring their academic achievement compared to the mental effort it took to get their given score. They used a pre/post-test setup, to measure any pre-existing differences between the groups, and also measured their academic achievements using a multiple-choice test. In this study, the flipped classroom students got a higher score than the control group, and they expressed that they enjoyed the availability and flexibility of choosing when they would watch the lectures at home.

Evrekli's study explored how well mind maps could be used to assess academic achievement, and they developed an assessment rubric that was then used to test their reliability. The assessment rubric was developed from earlier entries of mind map assessment rubrics, and they had two expert raters use them to see if they were consistent. The study found that the assessment was consistent and reliable, but it did also state that this was a field that was not studied extensively.

I decided to create a study that, similarly to Županec's study (2018), measured how the flipped classroom could affect what knowledge students gained in the classroom. I utilised Županec's design choice of having one experimental group (flipped classroom) and one control group (traditional classroom). I then implemented the method from Evrekli's study (2010) to use mind mapping and the mind map assessment rubric to measure the students' development. This was also done as I wanted to use a method that would be anonymous, and that could let the students express themselves creatively in their answers. I will go deeper into the thoughts behind my choices on this in chapter 3.2.

1.2 Content of the thesis

The thesis consists of 6 chapters. Chapter 1 is the introduction, containing the motivation behind the study, studies from my previous literature analysis on the topic, as well as presenting some of the key studies this has been developed from.

Chapter 2 contains the theoretical framework of the thesis. In this chapter, different key concepts and theories are defined, beginning with the flipped classroom in science education, as this is the main topic being studied and measured. Here I present the early entries of the teaching method, as well as a definition with examples, and some different benefits the method has to offer. After this, I present a possible definition of conceptual knowledge, starting with the more general perspective from psychology, before going more into the development of scientific knowledge. Next, I present what practical work is, as well as different arguments for why it should be included in science education. I then proceed to link the flipped classroom method with conceptual knowledge development and practical work, using different theories and models, to create a connection between the goals, design, and method of this study. After that, I present some theories around homework, and how it has been a topic of discussion throughout the recent history of education in Norway. Finally, I present what mind maps are; including their origin and purpose, different examples to show how they might have different structures, as well as the creation and purpose of the mind map assessment rubric, before finally presenting how they have been used in science education in previous studies.

Chapter 3 is the method section. Here I present my research design, before presenting the design of the teaching and the lesson between the flipped and the traditional classroom. After this, I present the ethical considerations that were made while designing the study. I then present the design and implementation of the pilot and the main study, which were both performed in a total of four classes. Here I talk about the samples in the working groups, as well as what happened during the data collection, and how the lessons were adjusted over time. Finally, I present the measures and decisions that were made throughout the design process of the study to uphold its validity and reliability.

In chapter 4 I present the analysis and the results. I begin by describing the analysis procedure, where I use an example to make it clear how the results were produced. I then present the results from the mind map assessment rubric, showing a couple of examples of how different mind maps scored differently, and I present the comparison between the different teaching methods. Lastly, I present the results from the questionnaire, as well as their purpose.

Chapter 5 is the discussion, where I examine the different results in chapter 4, and present the different implications and considerations that have been gathered from them. This is done through a combination of my own experience with performing the lecturing and tutoring in this study, together with the theory from chapter 2. Here I will also present a critical view of my method, discussing my choice of design, and how the mind map assessment fit into the purpose of the study.

Chapter 6 is the conclusion and outlook of the dissertation. Here I give a brief overview of what the study has answered the different research questions, and what implications the study has made from the findings and the theory together.

2 Theoretical framework

In this chapter I will present the theoretical framework of the study, by presenting and defining the different key subjects and theories used, using models and examples from previous research as a foundation.

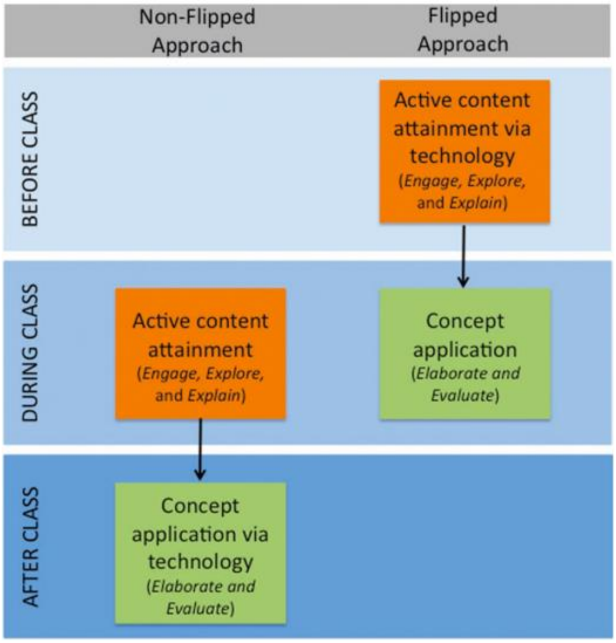
2.1 Flipped classroom in science education

The flipped classroom is most likely to have first appeared under this name in 2007 when Jeremy F. Strayer published his dissertation on the method in higher education. Here he addressed how flipping the classroom might be used as a response to the constantly developing technology, and also how professors have an increasing desire to create a more active teaching environment for their students (Strayer, 2007). Two professors who further tested and developed this theory for science education were Jonathan Bergmann and Aaron Sams (2012), who in 2007 began their research with their students during chemistry classes, and created a model that became one of the core foundations of flipped classroom teaching today, called the Flipped Mastery Model (Bergmann & Sams, 2012, p. 59).

The flipped classroom is a teaching method that is based on, as the name suggests, flipping the traditional structure of the learning experience for students. As Bergmann and Sams put it; “that which is traditionally done in class is now done at home, and that which is traditionally done as homework is now completed in class” (Bergmann & Sams, 2012, p. 13). According to multiple pedagogical learning theories, such as constructivist- and inquiry-based theory, teaching consists of two different phases. The first is when the learners are obtaining their conceptual knowledge (which will from now on be referred to as the obtaining phase), and in other studies, this part of the teaching is also called the pre-class activities (Loizou & Lee, 2020; Županec et al., 2018) or the content attainment phase (Jensen et al., 2015). The second is when the students have to apply this knowledge in different situations to deepen their understanding (which will from now on be referred to as the application phase) (Jensen et al., 2015, pp. 1–2). In traditional teaching, the obtaining phase takes place in class, where the teacher is responsible for presenting the content to their students, as well as being the holder of the information. The application phase then usually takes place at home, where the students are given the responsibility to apply this obtained information in their homework. In flipped classroom teaching, students are no longer responsible to apply their new information by themselves at home, as this responsibility has been shifted over to the teachers while they are at school. The students' responsibility is instead to obtain the first introductions through watching a video or another digital source (Jensen et al., 2015, p. 2). This means they have already been through the obtaining phase when they get to school, and they are prepared to apply their knowledge through active learning and group-based work in the classroom, where the teacher is present more as a support for the students (Cheng et al., 2019, p. 794; Erbil & Kocabas, 2020, p. 2; Županec et al., 2018, p. 163).

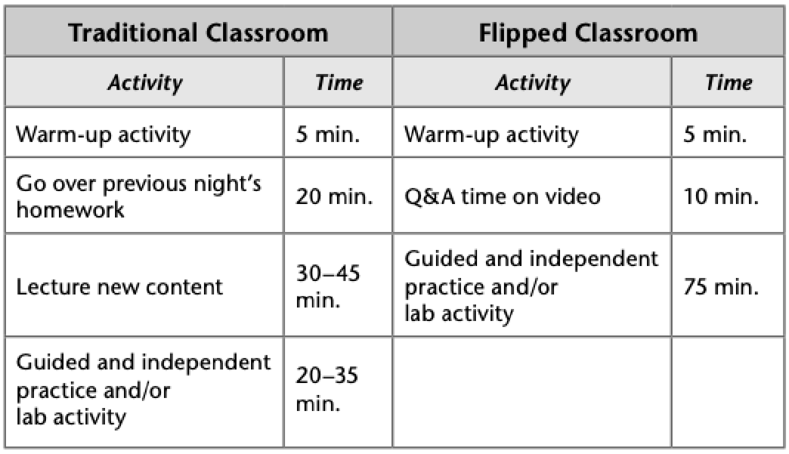
A study that was designed around this idea of content obtaining and content application in different phases was performed by Jensen, Kummer, and Godoy (2015). In their study design, they kept the teaching content similar, and structured it around Bybee's theory of the 5-E learning cycle from 1993, which stated learning took place in 5 cycles: engage, explore, explain, elaborate, and evaluate. In their study, they categorized these cycles into their different phases, where engage, explore and explain were considered a part of the content obtaining phase, whereas elaborate and evaluate were considered a part of the content application phase (Jensen et al., 2015, p. 3). Similar to Bloom's taxonomy (see chapter 2.2), these cycles represent and rank the different ways a student can obtain and use knowledge, and in Figure 1, we can see an example of how Jensen et al. used these to show the difference between the two teaching methods.

Figure 1: *The different study designs in Jensen, Kummer and Godoy's study (Jensen et al., 2015, p. 3).*



The flipped classroom method is meant to move passive learning, such as listening to a lecture, out of the classroom, giving more time in class for cooperative and active learning (see Table 2), so that the students can develop a deeper understanding of the content (Erbil & Kocabas, 2020, p. 2). This method is also meant to give students more control over their learning, as they have the opportunity to watch the lecture when it is best suited for them throughout the day (Strayer, 2007, p. 6). The video format is giving students the option to pause and re-watch certain challenging parts, so they can work more thoroughly through these, and prepare better questions for the next class (Bergmann & Sams, 2012, p. 24). In science education, this method could mean more room for experiments or other practical activities to lessen the abstract nature of some parts of the subject. Below is another example showing how the teaching methods can differ in the classroom gotten from Bergmann and Sams' study (Table 2).

Table 2: *Example of class time in the different teaching methods (Bergmann & Sams, 2012, p. 15).*



Traditional Classroom		**Flipped Classroom**	
Activity	***Time***	***Activity***	***Time***
Warm-up activity	5 min.	Warm-up activity	5 min.
Go over previous night's homework	20 min.	Q&A time on video	10 min.
Lecture new content	30–45 min.	Guided and independent practice and/or lab activity	75 min.
Guided and independent practice and/or lab activity	20–35 min.		

2.2 Conceptual knowledge in science

2.2.1 Psychological perspective on conceptual knowledge

Conceptual knowledge is a way of understanding a concept or an idea, through creating and organizing connections and relations between knowledge (Watson et al., 2016, p. 119). In 2005, Jon R. Star proposed that conceptual knowledge should be defined as the knowledge of concepts or principles (Star, 2005), meaning the knowledge of connections or relations between different bits of information. Looking into the field of Psychology, conceptual knowledge can sometimes be presented as having knowledge classes or schemas, as a way of processing information. These are mental building blocks, where people can put different information under a label, to create a knowledge network surrounding this topic (Mcleod, 2007). Conceptual knowledge would then be the overarching understanding one would gain from having well-connected and filled-out schemas surrounding the concept. The quality of conceptual knowledge is not only determined by the number of connections in the schemas, but also by their quality, as some connections may be more superficial than others (Baroody et al., 2007, p. 119).

Acquiring conceptual knowledge is not done through simply memorizing facts, as it implies having a more well-rounded understanding of the connections and procedures surrounding a concept (Watson et al., 2016, p. 2). A large part of primary school science education is teaching the students how the world around them works. In subjects such as chemistry and biology, this is more specifically done through teaching students about the structure and composition of matter, as well as their properties and interactions (Shana & Abulibdeh, 2020, p. 3). Students already possess many possible conceptions and misconceptions about how the world works from their everyday experiences, and by developing their conceptual knowledge, possible misconceptions can be replaced with conceptions, and their worldview is likely to move toward a more scientifically correct understanding (Edelsbrunner et al., 2015, p. 620). To get this kind of development, the students have to go through something called conceptual change, which involves restructuring previous knowledge, and integrating new information into their already possessed knowledge (Edelsbrunner et al., 2015, p. 620). In this case, a teacher has to be aware of what knowledge their students already possess, to be able to properly support the further development of knowledge (Johnston, 2005, p. 179). Looking back at Piaget's theory (Mcleod, 2007), this is comparable to adding new information to an existing schema in your knowledge network. If someone is struggling to integrate new information like this, the knowledge would be stored separately without any connections, and the schemas would be independent. This is called knowledge fragmentation. As conceptual knowledge is developed, more connections should be formed between concepts, resulting in a decrease of fragmentation (Edelsbrunner et al., 2015, p. 620).

2.2.2 Scientific conceptual knowledge

The goal of science is to describe and explain the world around us. This has to be done using systematic and argumentative methods, as in science, every assumption and implication has to be rooted in a reality that is observable (Sjøberg, 2009, pp. 63–64). Science education has the goal to develop three kinds of knowledge; 'what', 'why', and 'how to'. Knowledge 'what' is what most people refer to when talking about knowledge, as this is the factual knowledge gained in science that can be found in observations (Wenham, 2005, p. 2). This is where the students are taught about concepts, laws, models, and theories, and it helps create expectations of what is in the world around them. Having a well-developed knowledge ‘what’ could imply that the student is aware of a lot of scientific concepts, but they would not be able to do much with this information without understanding the ‘why’. A problem that can occur because of this, especially in primary school, is that a student (a) might assume that being able to use a scientific term in the correct context means they can understand a concept (Wenham, 2005, p. 14).

Knowledge ‘why’ is the reasoning behind the ‘what’, meaning that it tries to find explanations for the factual knowledge that is obtained (Wenham, 2005, p. 2). In this stage, the students are no longer just aware of scientific concepts, but they are now looking into why they behave or exist as they do. If the student (a) from the previous example uses a term in the correct context, but they lack an understanding and explanation behind the concept, this can trick the student into thinking they understood what they were expressing, which could lead to them thinking it is not necessary to further develop their knowledge about said concept (Wenham, 2005, p. 14). To develop this type of knowledge, the student has to look at the observations first, and then try to find causes and explanations for them, going through a process of discovery. This type of knowledge could be compared with the connections seen between concepts in a concept map or in a mind map, which is something I will discuss in further detail in chapter 5.4. The final type of knowledge, that is often overlooked, is the ‘how to’.

While ‘what’ and ‘why’ are concerned with knowing and understanding scientific content, knowledge ‘how to’ is concerned with the process of investigating and conducting the observations needed for the previous knowledge types (Wenham, 2005, p. 3). Students need to learn what is necessary to conduct fair testing, as well as the skills needed to be able to perform the test. This type of knowledge can be developed through experience with practical work, which will be discussed more in depth in chapter 2.3. If I can go back to the same analogy I used in the previous paragraph, to start creating a concept map or mind map, a student would have to know what it is, as well as how it is made. They would also have to know the purpose of the mind map, to know the reason why they are making it.

2.3 Practical work in science education

2.3.1 What is practical work?

Practical work is a feature of science education that has been utilised and studied extensively throughout the evolution of teaching and education. In previous research, practical work has been defined as "… any teaching and learning activity which involves at some point the students in observing or manipulating real objects and materials" (Millar, 2004, p. 2). This definition implies that the students are gaining *first-hand knowledge* by working with materials and objects directly. This implies they are not receiving *second-hand knowledge* from already processed information through literature and books, but are instead processing information from their personal senses and experiences (Marion, 2015, p. 107; Sjøberg, 2009, p. 403). Peter van Marion also specified that the definition is not limited to one location, meaning practical work can take place in the classroom, in a science lab, at home, or even out in the field (Marion, 2015, p. 105).

In many definitions of practical work, like the one presented above, some version of the phrase "observing and manipulating objects and materials" is frequently used (Abrahams & Millar, 2008; Marion, 2015; Millar, 2004; Sjøberg, 2009). This phrase is most often referring to the performance of, for example; student activities, lab exercises, or experiments. A common factor with these sorts of activities is that they are characteristic for scientific disciplines, and conform with the part of the definition of practical work that includes the discovery and processing of information. This means that not all active teaching methods are immediately categorised as practical work; with examples such as project-work, roleplaying, or problem-solving. While these activities are frequently used, also in science education, Marion states that they do not conform to teaching students "scientific methods", and are therefore not considered practical work (Marion, 2015, pp. 105–106). In his version of the definition, Marion also included that the observation and manipulation of objects can take place in any phase of the learning activity. He specifies this because he states that practical work does not only include "hands-on-activities", but also the cognitive processes that take place before or after the physical activity, as these are just as important to create meaning and knowledge from what has been conducted (Marion, 2015, p. 105).

2.3.2 Why should practical work be included in science education?

Per Morten Kind stated that it is important to remember that practical work could have very different purposes, depending on the topic, activity, or intention of the teacher. To create a clearer overview of the different goals of practical work, he made four different simplified categories of purposes (Kind, 2003, p. 239): The first purpose was that the students are becoming familiar with scientific phenomena, and learn about concepts, theories, or models that are describing these. The second purpose was that the students are learning about science itself, and how scientific knowledge is created and established. The third purpose was that the students learn to perform science, meaning they get to apply knowledge about methodology through planning and using tools, as well as practicing scientific discussion and argumentation. The last purpose was that the teaching creates interest and motivation for science by providing first-hand experiences. An immediate argument that supports the use of practical work, is that these four goals to a large extent align with the overarching goals in the science curriculum (Marion, 2015, p. 106), and I will go more into detail on the different purposes of practical work below.

Abrahams and Millar stated that "The fundamental purpose of practical work in school science is to help students make links between the real world of objects, materials, and events, and the abstract world of thought and ideas" (2008, p. 4). This quote reflects an idea that many studies use as a foundational argument for using practical work in science education. This idea states that through practical work, the students are practicing and developing skills that are transferrable to situations outside of school, as practical work is connected to multiple cognitive skills, such as being able to observe and interpret data, as well as being able to come to conclusions (Kind, 2003, p. 233). These are important skills to develop, as while in a working environment, the students will rarely receive information that has already been processed like they do in school. Instead, they have to learn to ask questions and figure things out themselves or together with others, so that they can process what information is handed to them. Doing this in the classroom through practical work could make this a more familiar process for the students in the future.

The idea presented above can also be specified to show how practical work can support students' understanding of science. Practical work allows students to observe that the content they are taught in science at school, is based on evidence from the real world, which then can give their education a sense of meaningfulness. When students participate in practical work, they can use their knowledge in realistic contexts that have some sense of familiarity with them. This can counteract the abstract nature of many scientific concepts, and can thereby further help the students understand the usefulness of their learning (Sjøberg, 2009, p. 405), and Abrahams and Millar stated that to progress in science, it is vital that students are exposed to this kind of understanding (Abrahams & Millar, 2008, p. 2). An example of how practical work can support this kind of development is having the students test out the theories they are taught, acting like scientific “myth busters”. What I mean by that, is that the students could try performing experiments referenced in the teaching or their books, or they could perform an activity that shows the application of a concept or a phenomenon that has been taught to them theoretically. By doing this, the students should be able to more easily comprehend their given information, as it is connected to a more concrete experience, and this should give them a sense of confirmation that the theory is correct (Marion, 2015, p. 117). As Sjøberg put it: this allows the students to better remember or “believe” the content of their learning, as they can see that it is confirmed in practice (Sjøberg, 2009, p. 404).

For the students to be able to see connections between the theory and their observations and experiences in practical work, it is important that they also learn about different forms of representation. Critics of practical work state that it is based too much on a positivist view of science, thinking that observations show the objective truth, independent of models, theoretical ideas, or previous studies (Marion, 2015, p. 111). Not every phenomenon can be explained by just simple observations, and we could never expect students to fully comprehend laws of nature or scientific phenomena, that which previous scientists have spent years studying to figure out (Kind, 2003, p. 234), but what we can do is to support students with ideas and concepts they will need to gain any knowledge from their observations during their practical work (Marion, 2015, p. 112). This includes for example teaching students about the correlation between the real world and models. Models are used to describe natural phenomena in a way that is more comprehensive, and it is therefore both beneficial, as well as important that the students are able to connect models with their real-life observations. This type of understanding and cognitive development is however not something that can be achieved by performing a couple of experiments, and it should be kept in mind as a foundation for all experiments with the students (Kind, 2003, pp. 240–241).

Practical work does not only have the purpose of supporting students in processing information and development of knowledge, as seen in the two last categories mentioned in Kind’s work at the beginning of this chapter. Abrahams and Millar mentioned that another important part of practical work is the practice and conduction of the hands-on skills they will need to further investigate their ideas and experiments (Abrahams & Millar, 2008, p. 2). While conducting practical work in science education, students are often expected to explore some phenomena or theory, that requires scientific measuring equipment supplied by the school. This lets the students become familiar with using different measurements and technical equipment, and gives them an understanding of how the equipment works. This can then give the students an arsenal and knowledge about equipment that lets them further investigate other scientific concepts in the future (Sjøberg, 2009, p. 405).

Lastly, Kind mentioned that practical work can contribute to creating variation in the classroom (see the beginning of this chapter). Unlike the previous arguments, this is not connected to the curriculum goals of science education, but rather to the individual teaching goals of science teachers, and it is still an important part of why practical work can be beneficial. Varied teaching is not a learning goal in itself, but it can rather act as a tool to help students reach their other learning goals. Interest and motivation are both cognitive states that we want the students to reach, as they can lead to a higher drive to do their tasks and learn about their content, and looking at the content presented above, one could argue that varied teaching from practical work could wake an interest in the students. (Marion, 2015, p. 108). Children possess a lot of curiosity about their environment, which drives them to want to discover how the inner workings of the world (Johnston, 2005, p. 168), as long as it is comprehendible of course.

2.3.3 Measuring the effect of practical work

To assess the effect of practical work, one has to look into how the different parts of the activities are working according to their intentions. Marion addressed this by creating a model that could support both the creation and the evaluation of practical work in science education (2015, pp. 108–109). First, the activity has to be designed in a way that makes sure the students are doing what is expected from them. If the students do not perform their expected tasks, this could indicate that the teacher did not properly present the learning goals of the activity, or that they did not fully consider the different students' prerequisites or the practical framework of the activity. The second part of the model is that the activity has to give the students their desired knowledge. This part is necessary because if the students are doing what is expected, this still does not guarantee that they are learning what they are supposed to from the activity. In the case of this happening, it is important to assess whether the individual prerequisites for learning are met, and one might have to adjust the activity or even the learning goals of the lesson (Marion, 2015, p. 108).

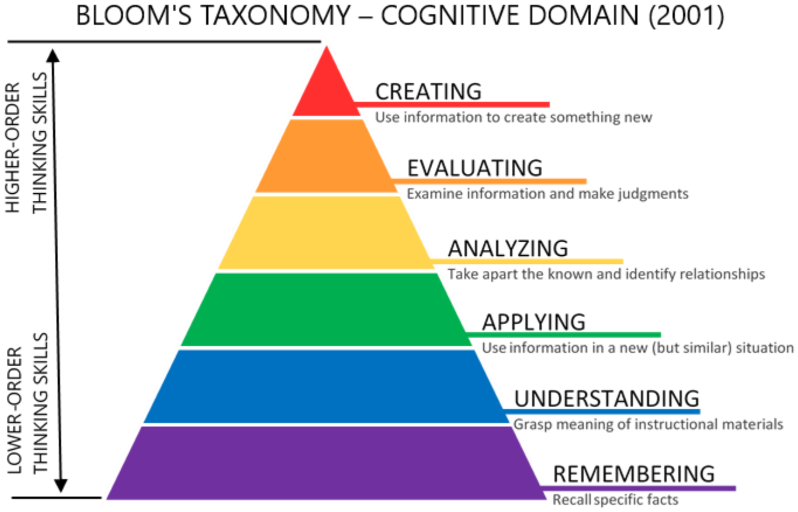
When assessing the effect of practical work, one also has to remember that practical work can have multiple purposes, which are not always connected to learning goals or theoretical knowledge, as stated by Kind in the previous chapter. One cannot therefore just ask if practical work is better than normal teaching, without providing any further insight into the intention of the lesson. If the goal is to develop practical knowledge about conducting scientific methods or using technical measuring equipment, then practical work would be able to provide more relevant knowledge than theoretical teaching. The same can be said when the goal is to develop the students' scientific confidence, as in practical work, students are taught that they can study something that is foreign to them, and still make completely valid observations that can contribute to the activity. If the goal of the lesson is to develop theoretical knowledge however, then it would be harder to see better results from practical work than theoretical work. This is because theoretical knowledge is often measured by a written or oral test. These forms of assessments are focused on, or rather limited to only one part of learning, and are therefore not able to include all the knowledge gained from practical work in the final results. If the final assessment contained a combination of theoretical knowledge and scientific methods however, the students would be able to apply more different types of knowledge, and practical work could give a better result (Sjøberg, 2009, p. 405).

2.4 Linking the flipped classroom, conceptual knowledge development, and practical work

Developing conceptual knowledge requires both learning the content, and also applying it in different situations and contexts, as stated in earlier chapters (Jensen et al., 2015, p. 2). In science education, flipped classroom teaching can be a tool that leaves more time for practical activities, thus giving students more time to apply their knowledge surrounding concepts (Shana & Abulibdeh, 2020, p. 1). Practical activities, particularly in science education, are natural ways for students to develop their familiarity with experimentation, both alone and in groups. In a lot of practical work, students may be asked to figure out how something works, or what is specifically needed in a given situation. In many of these cases, they will have to go through an experimental method, where they become familiar with the concepts of variables and constants. The students learn that they have to regulate some variables while keeping others unchanged, and they can thereby develop an understanding of causal relationships (Edelsbrunner et al., 2015, p. 2). Looking at the theory about conceptual knowledge, one can see how developing this requires students to link new information and impressions with their pre-existing knowledge, so that they can re-modify their misconceptions, and create conceptual change (see chapter 2.2). The constructivist learning theory states that students can achieve this conceptual change by interacting with their environment and their peers, letting them use their own senses and communication to create new meanings, which are both common components found in practical work (Johnston, 2005, pp. 179–180).

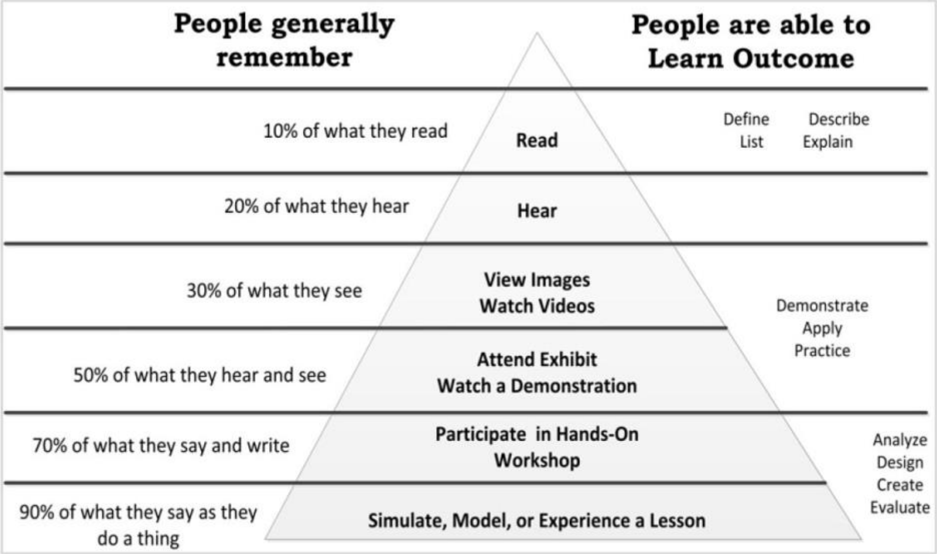
The significance of practical work can be further supported by Bloom's taxonomy, which is a model that categorizes and ranks the different ways someone can obtain knowledge (Figure 2). The model is divided into the categories; remember, understand, apply, analyse, evaluate and create, where remembering and understanding are the lowest order of thinking, meanwhile evaluating and creating requires thoughts of the highest order (Anderson & Krathwohl, 2001). The model states that the thoughts of higher order give the most development of understanding, but it also requires the most effort and knowledge from the student. This supports the theory that practical work is good for the development of knowledge, as performing practical work can often require students to analyse variables and measurements, evaluate the necessity of content, and sometimes produce new ideas and compositions. The flipped classroom model is a teaching method that seeks to give initial work that fits on the lower end of the taxonomy, meaning there is a lower effort required without the support of the teacher, in the early stages of learning a new concept. As long as the introductory video has given the students a sufficient baseline, there should be more time in class for higher order thinking through inquiry-based group work and active learning, resulting in students gaining a more developed conceptual knowledge to build onto their knowledge network.

Figure 2: *A model showing the different categories in Bloom's taxonomy (Krathwohl, 2002).*



In 1969, a different model was made by Edgar Dale, where he described how people learn and remember differently, depending on what actions they are doing while learning (Figure 3). The model states for example that students only remember about 10% of what they read, while remembering around 90% of what they talk about during simulations and activities (Shana & Abulibdeh, 2020, p. 3). Similar to Bloom’s taxonomy, this model ranks different ways of learning in a hierarchy, ranking them after how much the students remember and learn from the different methods. Looking at the bottom of the model, we can see that this further supports the necessity of practical work in the classroom. While students participate in hands-on activities and experiences, they retain a lot more of the information they are given, as well as develop the skills that we see higher in Bloom’s taxonomy. The model also states that the students remember more of what they are saying and writing during practical work, which emphasizes the importance of letting students talk and communicate about what they are doing while conducting experiments.

Figure 3: *The different stages in Edgar Dale's cone of experience (Shana & Abulibdeh, 2020, p. 4).*



Working with experiments in groups can help students develop their communication and cooperation skills (Sjøberg, 2009, p. 405). Studies have found that students who perceive their education to be meaningful, are more likely to seek valuable inquiry in dialogue with other students, and having in-class activities in small groups meant that the students had more opportunities to articulate what they knew to their peers. This lets the students create an understanding together with the other students, and learn from each other (Hofstein & Lunetta, 2004, p. 32), giving them more opportunities to get a more developed understanding of the relevant concepts (Shana & Abulibdeh, 2020, p. 3). A common issue regarding practical work is that a lot of teachers are experiencing that they do not have enough time to perform all the student activities that they would like (Marion, 2015, p. 109), and as mentioned in the previous paragraph, the flipped classroom method aims to change this by decreasing time necessary for theoretical instruction, leaving more room for active learning.

2.5 Homework and the debate around them

Homework could be defined as tasks given by a teacher that one is expected to complete outside of school hours (Askedal, 2016, p. 3). Traditionally, homework has been considered a part of learning that created responsibility and mental development that would be good for the future (Jerrim et al., 2019), so why has it been such a frequent topic for debate? The Norwegian school system has for a long time tried to give all students equal opportunities for development, and Norway is one of the countries with the lowest differences between students’ achievements (Nilsen & Bergem, 2015, p. 159). As research has shown that homework is one of the bigger contributors when it comes to differentiating students with higher and lower socioeconomical backgrounds (Nilsen & Bergem, 2015, p. 169; Utdanningsdirektoratet, 2021, p. 8), this naturally goes against the wish for equality that the Norwegian school seeks. Students with well-educated parents and a better economical background tend to benefit more from homework, as they usually have more available resources at home to support them with their tasks. Meanwhile, some studies have found that homework has little effect on all students’ academic achievements in primary school, as they are too young to have well-developed metacognition and self-efficacy (Hattie, 2010; Jerrim et al., 2019).

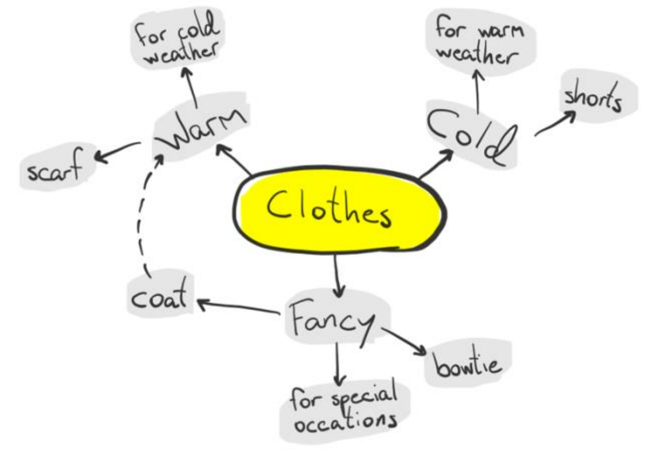
The flipped classroom method is designed in a way that would fundamentally change homework, as the more passive obtaining of information is done at home, while the more demanding and challenging application is done at school with the teacher present (Erbil & Kocabas, 2020, p. 2). This lessens how much help a student potentially needs from their parents or legal guardians, and moves this responsibility to the teacher. The parents still have to make sure the students watch their videos, but the academic resources in the home should no longer provide any different amount of support for the students.

2.6 Mind maps as a method for assessing conceptual knowledge

2.6.1 Mind maps

Mind maps and concept maps are both visual and structural learning strategies developed by Joseph Novak and Tony Buzan that have been widely used to map out and acquire knowledge in educational settings in a way that actively creates an interconnectivity between information and concepts (D’Antoni et al., 2009, p. 2). Figure 4 shows an example of what a mind map might look like. Although it is a simple mind map, it contains clearly defined groups and relations for its concepts, and it has a visible hierarchy between the concept links.

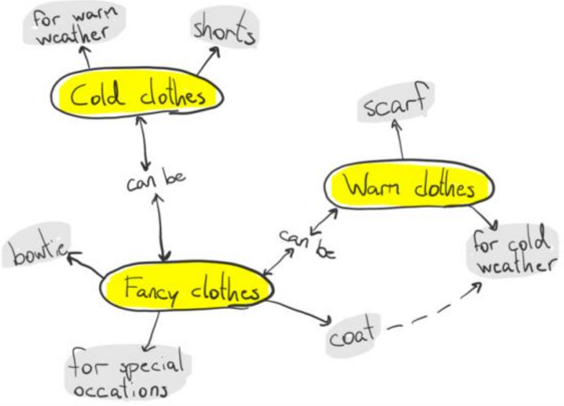
Figure 4: *Example of a mind map with a spherical structure.*



This mind map was made with a spherical structure, which Tony Buzan stated was inspired by Leonardo da Vinci's way of making notes (D'Antoni et al., 2009, p. 2). This is not the only way to structure a mind map however, as there are a lot of different ways to make a mind map. Different structures might be more or less suited for different tasks, and below are two more examples of the more commonly used mind map structures I found. Figure 5 shows a mind map with a tree-shaped structure, which has a more clearly defined hierarchy between its concepts, but is overall very similar to the spherical structure in its application. The mind map in Figure 6 has a very different structure type, which is understood to represent a more dynamic knowledge network, called a rhizomatic structure. This structure is less focused on working from one main topic and subcategories, and is instead focused on connecting multiple main concepts. This is also a structure that is more commonly seen in concept maps than in mind maps, and it could arguably be more accurate to call this a concept map.

Figure 5: *Example of a mind map with a tree-shaped structure.*

Figure 6: *Example of a mind map with a rhizomatic structure.*



Mind maps can help give us a visual understanding of what students know about a given topic or concept (Johnston, 2005, p. 60). While creating mind maps, students are encouraged to create an interconnectivity in their understanding, which allows them to integrate new knowledge with their pre-existing knowledge network (see chapter 2.2). Mind mapping can act as a more organized brainstorming activity, where the students not only show all their different associations to the concept, but also what connections they are able to form between them. If the students struggle to find their own words, they could still develop their conceptual knowledge by starting with an already prepared list of words, or a 'word-cloud' from a previous brainstorming, and linking these together.

2.6.2 Assessment of mind maps

As stated above, concept maps and mind maps are able to show the development and interconnectedness of students' understandings. Because of this trait, it has been found that analysing mind maps can be a useful tool for assessing students' ideas on a topic. Mind mapping can also make students more aware of their own learning, as it gives them a very visual representation of what they know, and after some experience with creating mind maps, they could be able to compare and reflect on how well developed their knowledge is on a given topic (Johnston, 2005, p. 180).

Table 3: *MMAR scoring system.*

1st level concept link	2 points
2nd level concept link	4 points
3rd level concept link	6 points
4th level concept link	8 points
Cross link	10 points
Example	1 point
Relationship	3 points
Picture, Image and Figure	3 points
Invalid component	0 points

The concept map assessment rubric (CMAR) is an assessment tool that was created to measure conceptual knowledge and understanding through a structural analysis of concept maps (West et al., 2002, p. 820). This analysis tool looks at the structure and connections between the different concepts to determine one's level of knowledge. Based on this assessment tool for concept maps, researchers have looked into developing similar assessment tools for mind maps (D'Antoni et al., 2009). There is little research into the use of mind maps compared to concept maps in education, and thus Evrekli, Inel, and

Balim further developed and tested a scoring system (2010, p. 2331) that was based on an earlier iteration of a mind map assessment rubric (MMAR) (D’Antoni et al., 2009). The scoring system included different scores for different levels of concept links in the mind map, and it also scored depending on the number of examples, images, etc. that all have been considered and are supported by literature relevant to their respected theories in learning (Table 3). Studies have shown that an increase in knowledge and understanding can lead to more elaborate and filled-out mind maps, and thus this way of scoring should be able to show if there is any noticeable difference in developed conceptual knowledge (West et al., 2002, p. 821).

3 Method

In this chapter, I am presenting the method of the study, which includes the design of the research and the teaching, as well as the conduction of both the pilot and the main study. I will also present the ethical considerations, validity, and reliability of the study.

3.1 Research design

This study aimed to look at how flipped classroom teaching can impact the development of conceptual understanding in primary school science. It is an experimental comparative case study of two teaching methods tried in three different classes, where they all were taught the same content. When performing a case study, the research takes place within a clearly defined context and creates what can be called 'local knowledge' (Postholm & Jacobsen, 2018, pp. 63–64), meaning the findings of the study are first and foremost a reflection on the performance of these specific classes, and it is not before the discussion one might see how these could imply anything outside of the given context. In one case, the introduction was designed as a traditional in-class lecture, whereas in the other case, the introduction was presented as a video. While the introduction was different between classes, all classes still performed the practical activity identically. This meant that the comparison was between the impacts of the different teaching methods, making this the cause for any effect that emerges (Postholm & Jacobsen, 2018, p. 70).

The study was performed in one group as a pilot, and three groups were used for the main study, all from different schools in Norway. The implementation and research were all conducted by myself between January and March of 2022, and all classes received the same content and instructions developed from the curriculum of LK20 (Kunnskapsdepartementet, 2020). A pilot was performed before the main study to figure out if the planned timetable for the lesson worked out as predicted in practice, and to discover any possible pitfalls and kinks in the lesson plan that would have to be revised and improved before beginning the main study.

The content of the study was taught in the topic of chemistry during science class. The flipped classroom group was given a 6-minute video to be watched at home, and the traditional classroom groups participated in a 30 to 40-minute lecture and discussion at school. After completing the introduction, both groups were given the task of constructing a mind map at home. After a period of two days, there was a short round of questions directed at the students, asking what was remembered from the introduction. This was then followed by each student answering an on-paper anonymous questionnaire, with the intention of exhibiting any possible differences in variables. After completing this, each class completed the chemistry activity at school, and at the end of the activity, the students were instructed to continue adding to their mind map, before it was collected by the teacher.

3.2 Teaching design for conceptual knowledge and practical work

The practical lesson that was planned for the study had the topic of chemistry and acidity, where the lesson plan I used for the activity can be found in attachment 1. I used this type of lesson plan design, as I had previous experience using this in my teaching practice periods, and I thought it worked well to set up the content of the lesson.

When I was designing the lesson, I had to choose a topic I would teach for the different classes. I decided early that the topic had to give a lot of room for student-centred learning, where I could act as a support, while the students were being responsible for their own learning. This was decided to minimize the amount of researcher bias affecting the outcome of the activity, which I will be talking more about in chapter 3.7. Chemistry is a subject that naturally fits practical work into its rubric, as the topics for primary school are more centred around chemistry that is observable in the students' daily lives, so this was the chosen subject of the lesson. I decided to have the students explore the concept of acidity. As the concept of acidity can be very abstract to students of this young age, the introduction had to be very foundational to avoid it from becoming overwhelming, and I chose to focus on chemistry in substances they observe in their everyday lives.

During the designing and performance of the questionnaire, it was also important that the questions were phrased in a way that was understandable to the students, so that they could provide valid answers. To make sure the questionnaire could serve its intended purpose in the study, I had to operationalise what I wanted to study. This meant turning the subject of my study into something concrete that could be measured (Postholm & Jacobsen, 2018, p. 167). As I wanted to measure the impact of the flipped classroom method, I had to create certain variables that could display the different impacts from this. An important part of flipped classroom teaching is its change to what is done outside of school, and as I will discuss further in the next chapter, the introductory part was the main variable between the cases. Because of this, the questionnaire wanted to mainly map out how the groups might have differed in this part of the study, and asked questions regarding whether they had completed the intended work at home, and what variables were present during this, like if they received any help, or if they used any other sources.

In the activity, the students made an indicator by cutting up red cabbage into thin pieces, before filling the container up with hot water. When being told what an indicator is, it can seem like a very foreign and difficult concept to grasp, so I wanted the students to get a first-hand experience with the fact that it is not the substance itself that makes the indicator, but the purpose it provides. I also used other names than ‘indicator’; like ‘cabbage tea’, or ‘cabbage water’ when referring to what the students had made, to try and emphasize this point that the name was not important. The students were then shown four substances in clear water bottles, that they had no idea what contained. These substances were dissolved baking soda, sparkling water, plain water, and dissolved citric acid. I made sure to use safely consumable substances, as the students were now going to use their senses of vision, smelling, and tasting to explore the contents presented to them. I was not looking for any right or wrong answers, as the goal was not to find the correct smell or taste, but rather to note what they experienced, and keep this in mind when discussing what it was. This way, I could help the students build their scientific confidence, by letting them know that all their observations were valid (Sjøberg, 2009, p. 405). After their observations were made, the students added their red cabbage indicator to the containers and observed how they all got different colours. If it was not made clear through the observations of sour and bitter taste, this then showed clearly that the substances had different grades of acidity.

The introduction was my opportunity to give the students some input, and the activity was where the students could utilise this input within a context, to properly understand what we had previously discussed (Jensen et al., 2015, p. 2). The red cabbage experiment was chosen specifically because it was practical work that gave the students a simple purpose they could work towards on their own. The design also let the students discuss in pairs what they were experiencing, so that they could formulate a better understanding of the activity, as well as retain more information in their memory (Edgar Dale’s cone of experience). The activity was designed around letting the students use many of their senses, to give them different types of information they could add to their knowledge network. All of this combined would allow the students to integrate new sensory knowledge together with the input from the introduction, to develop a more advanced conceptual knowledge on the topic (Edelsbrunner et al., 2015, p. 620; Watson et al., 2016, p. 2), and thereby help the students recognize common abilities and similarities in different acids, bases, and indicators in the future.

3.3 Lesson designing between flipped and traditional classroom

As I wanted to study the difference between flipped teaching and traditional teaching, I had to design a lesson that would be able to give the same content in both teaching methods. Looking back in chapter 2.1, I have discussed how the flipped classroom benefits from leaving more room for practical work. With this in mind, why did I decide to give the teaching methods the same amount of time for the activity? During the early stages of developing the lesson, many ideas were considered to fairly teach the same content with two different teaching methods, while keeping the comparison as fair as possible. While trying to create a design it was decided that I would not perform additional active learning with the flipped classroom, as this could create new variables that had to be considered; for example, if the additional activity was more impactful, or of a higher quality than the one both groups conducted. My bias as both the teacher and the researcher could have impacted what I decided to do similarly and what I decided to do differently, and I will discuss this more in the next chapter.

In the flipped classroom method, the teaching part, or the obtaining phase, is moved out of the classroom (Županec et al., 2018, p. 163), so I decided to start by separating the lesson into a teaching part and an activity part, similarly to the design found in the study by Jensen et al. (2015). This way I could have the activity be the same for all groups, and limit any other differences aside from the teaching part of the introduction, making the introduction the differentiating factor between the cases. This also meant I could focus my attention on the one part of the study, letting me go more in depth into how the teaching methods differed, and seek out any findings here. Before designing the introduction, I had already designed the activity, as the main purpose of the introduction was to prepare the students for what they would be doing in the activity. This is supported by previous research about practical work, where it has been stated that "*students' minds should be stimulated prior to starting any practical work by providing them with some background information on what it is they are investigating*" (Shana & Abulibdeh, 2020, p. 2). Table 4 shows an overview of how the two teaching methods compared in time and conduction.

Table 4: *A general overview of both teaching plans.*

Flipped classroom		**Traditional classroom**	
Activity	Time	Activity	Time
Introductory video to watch at home. Students are asked to make a mind map of what they learnt.	Before activity, 6 min	Introductory lecture and discussion at school. Students are given homework to make a mind map of what they learnt.	Before activity, 30-40 min
Short discussion on the content of the video.	5 min	Short discussion on the content of the last lecture.	5 min
Experiment with student centred activity in pairs.	40 min	Experiment with student centred activity in pairs.	40 min
Discussion about purpose with activity and connection to introduction.	8 min	Discussion about purpose with activity and connection to introduction.	8 min
Continue adding to mind map.	7 min	Continue adding to mind map.	7 min

3.4 Ethical considerations

In creating and writing a study like this, there are a lot of ethical considerations that have to be made, as I have to remember, before putting the research out into the open for display, that I have collected data from real people and not just numbers. While conducting research like this, one has to make sure the participants are aware and understanding of what they are a part of, as well as consenting to participate. There also has to be a reassurance that the collected data will be handled and stored confidentially, and that participation should have no consequences on the participants whatsoever (Postholm & Jacobsen, 2018, pp. 247–249). Finally, one has to make sure the conduction of the research and collection of data is handled as fairly as possible, and that bias I kept to a minimum to uphold the reliability of the study. These points were all considered through the different stages of planning and performance of the study.

The national rules in Norway state that any collection, use, or storage of personal data has to apply for an approval by NSD (Norsk samfunnsvitenskapelig datatjeneste). To keep the personal data of my participants private, I limited the data collection to include no personal data, where even I as a researcher did not know what the individual students had produced. This let me collect and store the data without any risk of exposing any personal information, as the only personal content I would have collected would be the students’ handwriting. The students were informed of this anonymity clearly before participating in the study, and it was made clear that their participation would not affect their ability to join the activities we were going to conduct to avoid any peer pressure from their other classmates (Postholm & Jacobsen, 2018, p. 248). This was a necessary procedure, as the conduction and collection of data would replace their usual science classes for a week, and I could not pressure any students away from learning the content of the lesson plan.

After informing the students of the study and their role as participants, each student was given a consent form (see attachments 4 and 5) that would have to be filled out by one parent or legal guardian. As the students were under 15, they were not old enough to have a complete understanding of the consequences of participation, nor did they possess the ability to fully consent to participate, and the parents or legal guardians would therefore also have to be made aware of what their children were participating in (Postholm & Jacobsen, 2018, p. 247). In this consent form, it was also stated how the students could retract their consent at any given time without any consequences, and that no personal data would be collected or used against anyone. I also made sure to only collect the questionnaires, as well as the data, in the form of paper, to have there be no way of tracing where they were collected from using an IP address.

3.5 Pilot study

3.5.1 Sample

The pilot was performed in a 5th-grade class, where a total of 11 students participated in the study. This group was younger than the intended age group that would later participate in the main study, but this did not end up being a problem. The main focus of the pilot was to test out the time parameters and design of the lesson plan, and not their actual mind map scores, so their lesser development and scores would not be a relevant factor to the success of the pilot. This being said, mind maps were still collected to practice and test out the scoring system in the MMAR.

3.5.2 Design and implementation

As the pilot group did not have any previous experience with flipped classroom teaching, the traditional classroom method was used. The introduction was designed to last about 10 – 15 minutes, as this would be a similar duration to the video in the flipped classroom method. I decided to keep the introduction this short, as studies have shown how long videos in the flipped classroom method can lead to the students getting bored, decreasing their chance of completing the entire video or doing the given tasks at home (Askedal, 2016, p. 63; Loizou & Lee, 2020, p. 11).

The lecture introduced the students to the concept of acidity, where the content included very basic knowledge, for example, that acids are sour, that bases are bitter, and how indicators can change colours in different acidities. This was paired with basic explanations of acids, bases, and indicators, so they could connect these terms and create an understanding of the main concept. After the introduction, the students and I created a mind map together on the whiteboard, to visualise what they had learned throughout the lesson. This was also done to give the students an example of how a mind map could be structured, so they had a point of reference. Using this knowledge, at the end of the lecture, the students made a mind map of their own that would later be used after the activity.

Two days after the introductory lecture the students participated in a questionnaire consisting of four questions (two additional questions for the flipped classroom design) regarding if they participated in the introduction, if they completed their homework, and what kind of support they received or used while completing their homework. After completing the questionnaire, the students then participated in an experiment about acidity at school. In this experiment, the students were put in pairs and presented with a bigger container, some red cabbage, 4 small containers, and some equipment for taking notes (Figure 7). In front of the lab, I presented 4 different substances that the students would all recognize from the introduction, and the purpose of the experiment was to use their recently gained knowledge to study these substances, and to find their connection to acidity. The students filled the big container with red cabbage and warm water, to create what would later act as an indicator. They then proceeded to put the different substances into their four small containers and took some notes on what they observed. After all substances were observed, the indicator was added to the four containers using pipettes, and every substance produced a different colour (see Figure 8). This led to a discussion about the indicator and the different levels of acidity between the substances, and the students sorted the containers to create their own acidity scale. A fifth substance was also present in case there was extra time left. After talking about the activity and its connection to the introduction, the students were given the task of making a new mind map, where they could include their previous knowledge from the introduction, as well as any new knowledge they gained during the experiment.

Figure 7: *The workstation each student pair started with.*

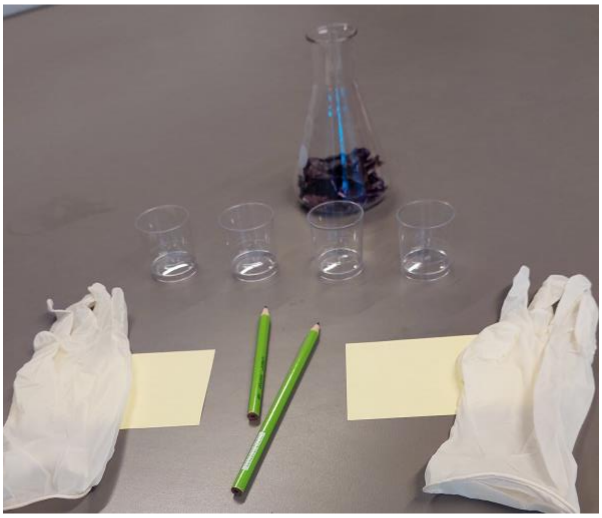


Figure 8: *The different substances after adding the indicators and sorting them by colour.*

3.5.3 Observations and ideas gained from the pilot

While performing the pilot in the traditional method, I had a realization about a key difference between the teaching methods. The introduction took a substantially longer time than expected, as the students asked lots of questions and wanted to contribute with their previous experiences on the topic. This important part of the traditional teaching method was overlooked during the planning stage, and so it was estimated that the introduction would only require 10-15 minutes. However, the class required closer to 45 minutes, as they were very engaged with the material and the surrounding discussion. I originally wanted to keep the introductory lecture around the same length as the video used in the flipped classroom method, to limit the difference between variables, but this did not leave any room for discussion or questions. I quickly realized that keeping the introduction the same length as the video would not be a fair and true comparison between the two teaching methods, since, in flipped teaching, students have the opportunity to pause, rewind and re-watch the video, whereas traditional teaching is more dependent on students asking questions to make sure they understand the topic.

The experiment also took a lot longer than expected to complete, as there was a lot of time spent on mixing and pouring the different substances into the small containers, and the students had to cut the red cabbage into thin pieces on their own. The class teacher was present and able to help the students, but the whole situation was clearly disorganized with different students finishing their observation-stage earlier than others. Towards the end of the session, there was no time left for the students to make mind maps, and I had to come back another day to finish the study. As the content was no longer as fresh in the students' minds, this clearly affected the final mind maps of the students.

3.6 Main study

3.6.1 Sample

The main study was performed in three 7th-grade classes, one flipped classroom group and two traditional classroom groups, where all groups were from different schools. I chose to study 7th-grade students, as it is the oldest class in the Norwegian primary school, and therefore provided the most cognitively developed students for understanding scientific concepts. The Norwegian school also uses mind mapping frequently throughout the later years of primary school, so 7th-grade students would be the most comfortable with using this learning strategy. The flipped classroom group consisted of 13 students, and was chosen as they had already used this teaching method for a while, and were therefore familiar with the format. The first traditional classroom group consisted of 10 students, and the second traditional classroom group consisted of 9 students.

As this research was conducted during the COVID-19 pandemic, there were some complications with the working groups. The flipped classroom teaching was completed with just a few students missing. For the traditional teaching group however, the first group ended up missing a lot of students because of contamination, or missing consent forms from parents. This led to many students missing the introduction before coming to the activity, and a low number of data samples, and thus some trouble with the variables between the two working groups. It was therefore decided that another control group using the traditional classroom method would be included in the study, to even out the difference in samples, and to properly study a group that has participated in both parts of the experiment.

3.6.2 Modifications to the design after the pilot

Whereas the pilot only included the traditional classroom method, the main study naturally included both the flipped- and the traditional classroom method. The video recording ended up lasting around 6 minutes, and the video and the physical lecture both consisted of the same presentation, sharing everything from pictures and figures, to the structure and content provided by myself. The only difference was the time allotted for discussion and questions.

After the pilot was complete there were a lot of adjustments made to the lesson plan. As stated in the pilot section, the introduction took a lot longer than expected, and thus the final version of the introduction in the traditional teaching group was altered to last between 30 and 40 minutes as opposed to 10 to 15 minutes.

The experiment was also altered for the main study in order to save time. In the pilot, a lot of time was wasted mixing substances and moving around the classroom, so for the main study the solutions were all mixed before class, and the red cabbage was cut just before the students entered the room. Having the substances mixed before class also allowed the experiment to have a slightly different purpose. The four substances were all mentioned in the introduction, but the students did not know what the different substances were. This meant they had to look, smell, and taste (optional), as well as use their gained knowledge from the introduction to decipher what I poured into their containers. After revealing the substances, there was a discussion about their different grades of acidity and how their senses, like tasting, could help them identify the content.

The way the students created their mind maps was changed as well. Originally, the students created two mind maps: One after the introduction, and another after the experiment. The students quickly let it be known that this felt redundant, as they were just repeating themselves, and the motivation to make the second mind map was not as high as with the first one. With this in mind, the final design of making the mind maps was changed, and the students no longer had to make two separate mind maps. Instead, they were to make the beginning of their mind map as homework between the introduction and the activity, and then they would finish it after going through the activity.

3.6.3 Data collection

As stated above, there were a lot of changes made to the main study. The first thing to note was the new time adjustment for the introduction. With more time available, the students were able to discuss in pairs for longer, which made them appear more confident in contributing to the class discussion. For the first traditional group, the students were noticeably quieter than the pilot group, and thus required far less time on this part of the study. The second traditional group was more interested in the topic however, and made more use of the extended time.

While filling out the questionnaire, it came to my attention that not all students seemed to answer truthfully, as some of them barely spent any time reading the questions, and just ticked yes on almost every question. While handing out the questionnaires, I made sure to clearly point out that I wanted them to answer honestly, and that I would not know who answered what. I also told them that I would not be offended if anyone answered that they had not done their homework, as they would be able to work on it after the activity.

For the experiment, the changes also seemed to make an impact on most of the students. In the main study, there was a layer of discovery and curiosity added, to give the students more motivation to complete the task. As the different substances were poured out, there was a lot of whispering and visible curiosity about what it could possibly be. As the students observed the substances, there was already much speculation in the classroom about their contents, and this further enhanced their desire to continue the experiment.

As there was a lot of excitement when mixing the colours and tasting the substances, the students had to spend some time settling down before the group discussion could take place. After eventually getting to the discussion, many students showed that they understood the connection between the content of the introduction and the activity. Putting this understanding into words did however seem like a bigger challenge, and a lot of students had some trouble adding any further concept links to the mind map, beyond what colours the different substances got.

3.7 Studies quality

3.7.1 Validity

In this section I will talk about the validity of this study, and what was done to try and uphold it. This study aimed to look into the effect of the flipped classroom teaching method, specifically on conceptual learning in primary school science. I have previously pointed out how earlier theory stated that there was a lack of research on this matter (Županec et al., 2018, p. 163), and it was therefore decided that I would partially recreate one of the previous studies as a case study, to add to the pool of existing research. As this was a partial recreation, this gives the study some indirect assurance that it properly researched what it wanted to find out, as earlier studies have used similar methods and analyses. This point is also applicable when it comes to the method of collecting data, as the mind map assessment took place using a pre-existing scoring system that had been studied and tested for reliability and validity (D’Antoni et al., 2009; Evrekli et al., 2010).

This ensured that the weighing of the points was well thought out, and that it came from peer-reviewed articles that had produced decent results.

Another argument supporting the validity of this study is that the method of data collection was well fitted for its task. The study aimed to measure the development of conceptual knowledge, and mind maps are designed to let someone present their knowledge about concepts and the relationships between them (Evrekli et al., 2010, p. 2330). This fit very well into Watson's definition of conceptual knowledge (Watson et al., 2016, p. 119), and thereby supported the use of this method. As mind mapping is a very visual learning strategy, it gives the students a lot of freedom in trying to display the network of knowledge they've gained from the introduction and activity. The MMAR that aimed to score the mind maps was developed from a structural method of assessing concept maps, which focused more on the structure and connections between concept links in a mind map, instead of assessing the quality of the individual concept links like in the relational method of assessment. This method's ability to measure knowledge and development has been tested and studied before with positive outcomes (D'Antoni et al., 2009).

As this was a case study, with the limitations of a master's study, I picked out one key difference between the flipped classroom and the traditional classroom that I wanted to look into. I chose to look at the difference in the knowledge obtaining phase of the method, and kept this as the only difference between the working groups. This gave the study a clear causal relationship between variables and results, and made sure that the study was given results based on the intended differences. This meant giving all groups a period of two days between introduction and activity, and that the activity would be the same length, with the same content. This might not reflect the everyday differences between flipped classroom learning and traditional classroom learning however, so it needs to be clear that these results are representative of the difference in the obtaining phase.

3.7.2 Reliability

In this section, I will go over what was done in the study to uphold its reliability, and what could have been done differently. As I was both the researcher and the conductor of the experiment, there are some points here that need to be addressed. Having the researcher conduct the teaching in the experiment could cause some researcher bias that can contaminate the reliability of the study, as it is impossible to stay completely neutral.

It was still decided to be done in this matter, as it was thought that having two different teachers perform the experiment would come with a higher risk of the classes receiving different content, or at least receiving the content at different levels of depth or clarity. Having teachers follow a pre-made lesson plan was also considered at some point, but this was disregarded as the teachers could have had different amounts of previous experience with the teaching method, and thus the students would once again receive different levels of support for their learning. These points do not however suggest that having an outsider conduct the teaching would give the students their full potential for learning, as their teacher has a better familiarity and understanding of what their students' needs are in a teaching scenario.

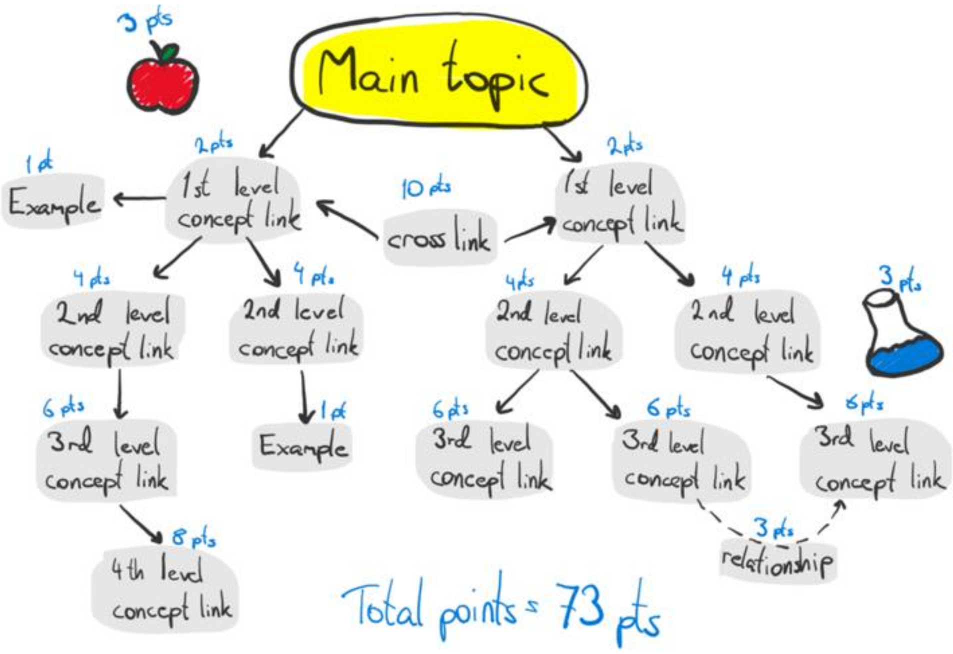
Being both the researcher and conductor of teaching, there were some further measures made to maintain reliability in the design of the lesson. As mentioned in chapter 3.2, the lesson was designed to be as student-centred as possible, letting the teacher be more of a supportive guide through the activity. This was intentionally done, because with myself being in a more supportive teaching role it would have a smaller effect on the final result of the activity, allowing the students to be the defining factor instead. This gives the study more reliability, as it means that if I were to be replaced with another researcher, the students would still more or less go through the same activity, and have the same experience as they did with me. Unfortunately, because of the small sample size, the results are not very generalizable outside of this specific case, but the design of the method would likely be something other researchers could recreate with only a few adjustments.

4 Analysis and Results

4.1 Analysis

The purpose of the analysis in a case study is to contribute to the description of the case and the context behind it. The analysis wants to seek out a purpose behind the collected data, and display it for the rest of the study (Postholm & Jacobsen, 2018, p. 157). The analysis of the collected mind maps was performed using the MMAR to give them a score, and a two-sample T-test was used to calculate for statistical significance of the different results. As the sample size was fairly small, the t-test results were also supported by data collected in the form of a questionnaire, to allow interpolation for new data. The scoring system in the assessment rubric gave points based on the structural components and connections in the mind maps, given that the content and placement made sense and that they were valid (Evrekli et al., 2010, p. 2331) (Table 3). It should also be noted that in the cases where students repeated themselves, the highest scoring component was included and scored accordingly, and all duplicates were classed as invalid. After the completion of the lessons with both groups, all mind maps were graded, and their scores were typed into Excel for calculation and comparison. Figure 9 shows an example of how the MMAR was used while scoring the mind maps.

Figure 9: *An example showing how the MMAR scoring system is used.*



The questionnaire contained yes/no questions, with the purpose of supporting any arguments and results that could emerge from the MMAR analysis. The final result from the questionnaire represented the percentage of students from their respective teaching methods that had answered yes to each question, giving a view of how the different groups acted on the different points included in the questionnaire.

As mentioned above, a two-sample t-test was conducted using R studio to test whether the difference between the mean scores between the flipped classroom and the traditional classroom was significant or not. The T-test measures the difference between scores compared to their respective sample sizes, which gives us a t-value representing the difference in the samples and a p-value representing how likely it is that the results appeared by random chance or luck. If the p-value came back higher than 0.05, that would mean there is a significant difference. Because the sample size was as small as it was, there were some prerequisites that needed to be met for the given value to be valid. A prerequisite for conducting a T-test is that there is a normal distribution in the samples. A Shapiro Wilk normality test was therefore conducted to confirm normal distribution for both traditional classroom and flipped classroom variables. In the Shapiro Wilk test, both variables had to come back with a p-value of more than 0.05 to ensure normal distribution was present.

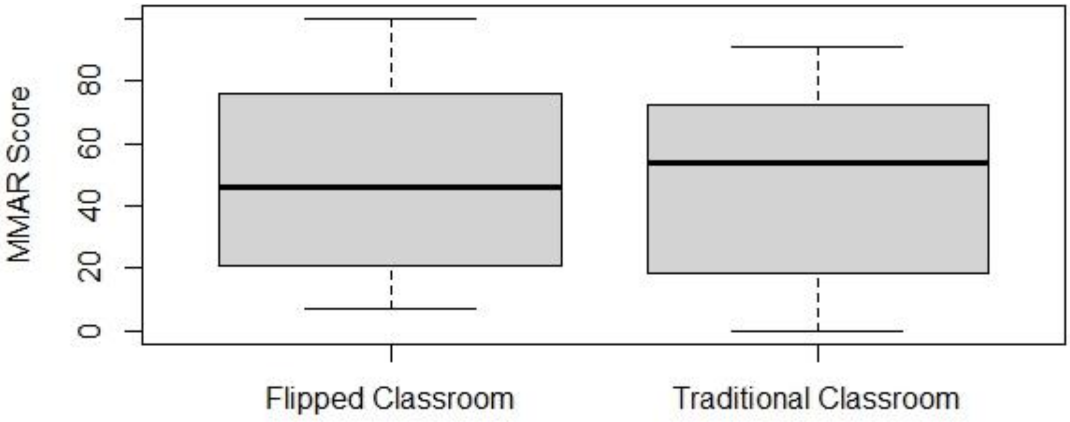
4.2 Results from the mind map assessment

After using the MMAR, it was found that the total mean scores of the mind maps between the two teaching methods were very similar, with traditional teaching having 48.72, which was 1.72 points more than flipped teaching with 47.00 (Table 5). The flipped classroom group scored on average 34.31 from concept links of different levels, which was 4.32 points less than the traditional teaching group. However, they did score higher in cross links, examples, and in the use of figures. In Figure 10 you can see a box-plot graph representing a comparison of the final scores between the flipped classroom group and the traditional classroom group.

Table 5: A comparison of the different score categories.

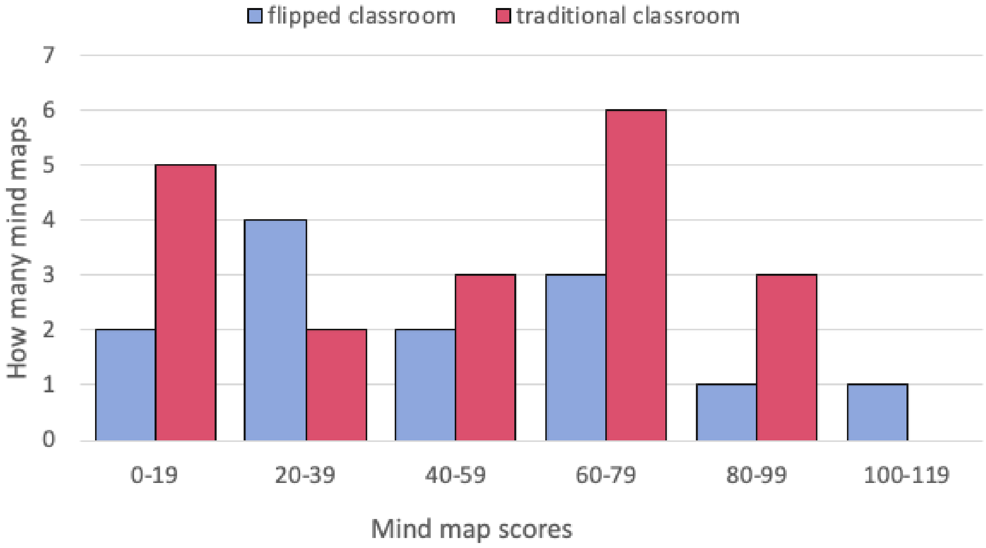
Category	Flipped mean scores	Traditional mean scores
Concept links	34.31	38.63
Cross links	3.08	2.61
Examples	8.69	7.32
Relationships	0.00	0.16
Pictures/figures	0.92	0.00
Total mean score	**47.00**	**48.72**

Figure 10: *A box-plot representation of the mind map scores between the teaching methods.*



The mean scores between the groups were very similar, so below is a closer look into the distribution of the differently scored mind maps (Figure 11). As shown in the graph, the traditional classroom had two score groups that stuck out more than the others, with the biggest mind map group being in the 60-79 score range, and the second biggest group being in the 0-19 range. The flipped classroom had a smaller sample size, so the difference is not as big, but we can see that the biggest mind map group here was in the 20-39 score range, and the second biggest was in the 60-79 range.

Figure 11: *A distribution showing how many mind maps there were in each score-range.*

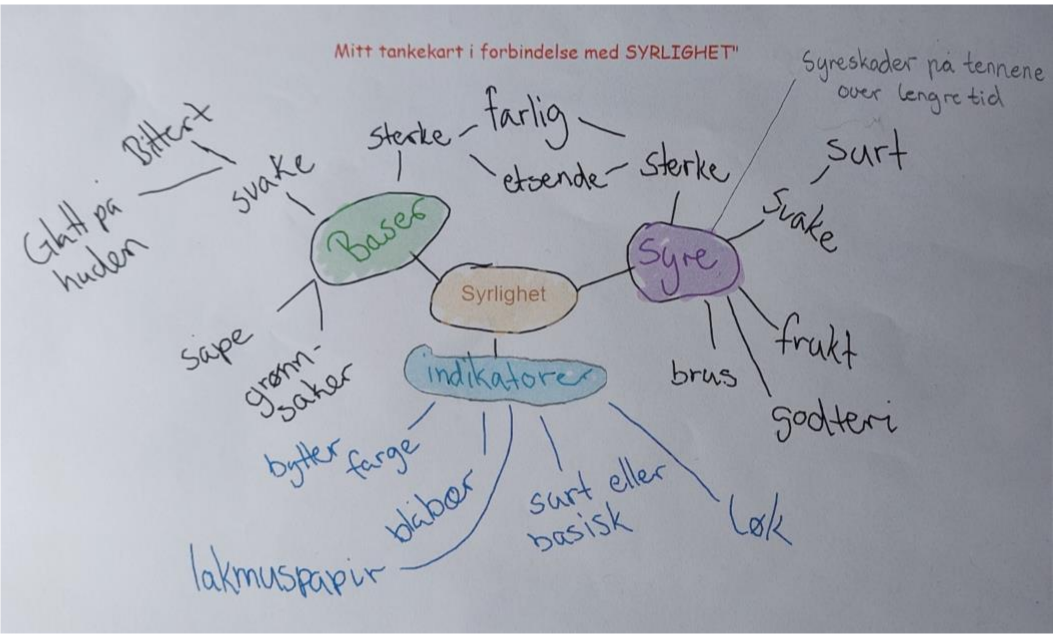


One of the reasons the complete mean scores were so similar was that even though the traditional classroom had more mind maps in the upper-middle range, the flipped classroom had few mind maps in the lowest score range compared to the traditional classroom, as well as being the only method with a mind map in the highest 100-119 score group.

4.2.1 Examples of differently scored mind maps

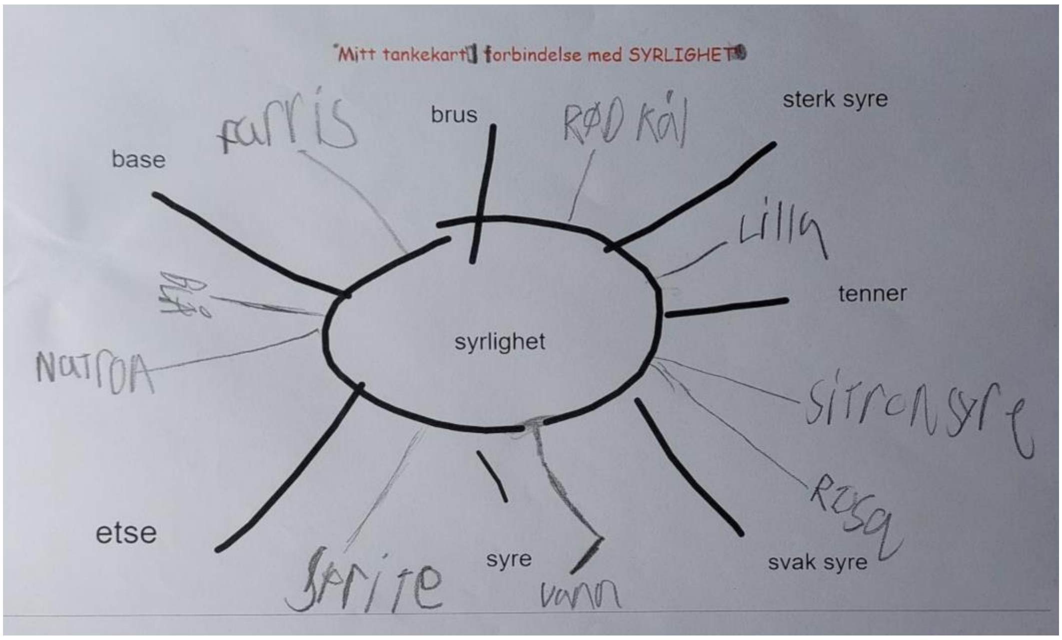
Below is a common example of how a mind map could score higher than another. In the first mind map (Figure 12), the student started with some of the main concepts in the centre, and then proceeded to connect abilities and examples to their correct concepts using a spherical structure. This gave the mind map a hierarchical structure, and it scored high in the MMAR scoring system. If we compare this to the second mind map (Figure 13), we can see that they have a very different approach.

Figure 12: *Example of a higher scoring mind map.*



Looking at the mind map in Figure 13, one can note that this mind map also had a lot of points. However, this mind map scored much lower due to its lack of structure and connectivity. In this mind map, the student had put down a lot of concepts and examples, but they were all only coming from the main topic, and they did not connect them to each other in any way, making them appear more like random points with no display of continuity.

Figure 13: *Example of a lower-scoring mind map.*



4.2.2 T-test results

In the Shapiro Wilk test, the flipped classroom got a value of p = 0.30, while the traditional classroom got a value of p = 0.06. As these were both higher than 0.05, the distribution was considered normal. An F-test was also conducted to confirm equal variance, and gave the result p = 0.94. This confirmed they were equal in variance, and therefore all assumptions were met for the two-sided T-test. The T-test was conducted, and produced a t value of -0.13, and p value of 0.89. This confirmed that the mean scores for the flipped classroom method and the traditional classroom method were not significantly different from each other (Table 6).

Table 6: *T-test results for mind maps scores according to the MMAR between the groups.*

Group	n	$\bar{x}$	t	p
Flipped classroom	13	47.00	-0.13	0.89
Traditional classroom	19	48.72		

4.3 Results from Questionnaire

The purpose of the questionnaire was to give further insight into the results from the mind map analysis. The flipped classroom group had a slightly higher completion rate for the pre-class activities, and the traditional classroom group had a higher percentage of students who received help from sources other than the introduction (Table 7). The results also showed that only a few of the students watched the video multiple times, but the majority paused or rewound certain sections.

Table 7: *Results from the questionnaire in percentage.*

Question	Flipped classroom	Traditional classroom
I have seen the video / I attended the introductory class	92.3%	84.2%
I made a mind map at home before class	92.3%	73.7%
I used aspects of the teachers mind map to help me make my own	61.5%	68.4%
I got help from other sources (parents, books, internet)	7.7%	21.1%
I saw the video multiple times	38.5%	n/a
I paused or rewound while watching the video	69.2%	n/a

5 Discussion

In this section, I will discuss how this study has answered my research questions; “How does flipped classroom learning impact conceptual knowledge development in primary school science?”, “What teaching method is more efficient?”, and finally “How could flipped classroom teaching be a possible solution to the homework debate?”. I will start by presenting a short summary of the key findings of my study, so these are clear and easily available while reading the discussion. After this, I will discuss how the flipped classroom performed in light of efficiency and availability, in light of my research questions. Then, I will discuss the design of my study, and how it impacted the results I found, before finally reflecting on the method and discussing the use of mind maps for assessing conceptual knowledge, presenting possible considerations and changes that should be made for future studies on the topic.

5.1 Summary of the results

The analysis of the results from this study showed that the mind maps scores between the flipped classroom and the traditional classroom had no significant difference, and this data suggests that there is no significant difference in the development of conceptual knowledge for the students between the two teaching methods. The two teaching methods did however have a different amount of time allotted for the completion of the study, as the students in the traditional classroom spent two science sessions at school, while the flipped classroom simply watched a video before participating in the practical session. The questionnaire also showed that more students in the flipped classroom completed their assigned homework than in the traditional classroom, and that more students in the traditional classroom groups received help from home while completing their homework.

5.2 Impact of the Flipped classroom method

In my earlier research, flipped classroom learning showed to have a noticeable improvement on students’ academic achievements (Table 1). In this study, that was not the case, as there was no significant increase in conceptual knowledge shown from the results in the flipped classroom method compared to the traditional classroom method. This is because of multiple factors, including the design of my study, the sample size, and the time allotted for data collection. While the scores had no difference, this does still provide some insight into the availability of this teaching method. Getting a similar result implies that the video introduction had the ability to sufficiently replace the longer introductory lecture that was presented in the traditional teaching, which leads me to my next point; time.

The design of the study was made in such a fashion that the two teaching methods had different knowledge obtaining phases, being the introduction and video recording in this case, and identical application parts, being the homework and the activity. This difference meant that the traditional groups had their introduction at school, and would therefore require one in-class session more than the flipped group to receive the same content. I will discuss the implications and decision behind why I designed it like this more thoroughly in chapter 5.4, but essentially, getting practically equal results whilst having less total time could imply that the flipped classroom was more time-efficient.

An important argument supporting the flipped classroom method is that it leaves more time at school for active learning and group work (Županec et al., 2018, p. 164), and if the teaching methods were given equal amounts of time, the flipped classroom students would have one more session to move on to another subject faster, so the teacher could cover a broader spectre of information if they chose to. In other scenarios, this extra time could also allow the students to continue working on the same subject, to apply their conceptual knowledge through discussions or other activities in practical work. These kinds of activities give students the opportunity to create new knowledge together with their peers (Johnston, 2005, pp. 179–180), which they then can connect to their previous knowledge, and get a more developed conceptual understanding (Edelsbrunner et al., 2015, p. 620). This is also a method of working that is closer related to what students might experience in their adult working life, where they have to cooperate in teams to achieve their goals. Relating their education to life outside of school is another important part of practical work (Abrahams & Millar, 2008, p. 4), as students get to practice and develop skills related to problem solving, scientific methods, and discovery. These points all imply that if there is time saved to do more practical work, the students would have more time to develop a lot of different types of knowledge and skills, that can be beneficial for their future learning and life after school.

Time spent is however not only a factor for the students' development, but also for the teachers work and preparation. Flipped classroom teaching requires a higher level of technological literacy and competence from the teachers, as the students are depending on technological mediums to acquire new conceptual knowledge. Flipped classroom teaching makes use of video lectures, and in this study, the video was made by myself. This video in particular did not take any longer to make than the physical lecture for the traditional classroom groups, but this could vary depending on how much effort one chooses to spend making the video. In the short term, this means that the time it takes to plan and produce the video lectures could be similar to the planning of a traditional lecture. In the long term, however, a teacher could simply re-use their previous video, assuming that the content is still up to date and relevant.

5.3 Adaptability of the flipped classroom and homework

One of the aims of flipped classroom learning is to reduce the impact socioeconomic backgrounds has on students learning by moving difficult tasks from the home to the classroom, but it also adapts its education through other means. As Bergmann and Sams put it, the flipped classroom "speaks the language of today's students" (Bergmann & Sams, 2012, p. 20). Children grow up using all kinds of technology, and learning from platforms such as YouTube is not foreign to the majority of students today. This means that the classroom is actually being pushed towards the comfort zone of the students, and can thereby possibly make a bigger impact on their motivation for learning. Another way flipped teaching adapts for students is the amount of work that is expected to be done at home. Research shows that students today spend a lot less time doing homework than they did previously, as this time is replaced by various social activities and sports (Utdanningsdirektoratet, 2021, p. 5). As the lectures are found in short online videos, students can spend less time doing homework, as well as decide when it is best suited throughout the day (Bergmann & Sams, 2012, p. 22).

While the main comparison between the teaching methods was measured with the scores from the MMAR, the questionnaire data also served an important purpose as interpolation to support any arguments for or against the research questions. By looking at this dataset, we could identify some variables that were worth mentioning. The first difference that stuck out was the percentage of those who completed the at-home work, where the flipped classroom group had a notably higher percentage than the traditional classroom group. This agrees with previous literature in that the flipped classroom could be a possible answer to improving students' motivation for homework. This can be further supported by the results from Askedal's study, where student interviews showed that the students in a flipped classroom understood the importance of the pre-class activities (homework) more so than when they were using the traditional method (Askedal, 2016, p. 64). In the same study, 40 out of 47 students answered that they previously only did their homework to avoid getting a warning/consequences from their teacher (Table 1), but that they now saw how it was important for their learning and development (Askedal, 2016, pp. 57–58).

The next notable difference from the questionnaire was how many students got help from outside sources, such as their parents or the internet. While the mind map scores had no significant difference, the traditional classroom students still made more use of outside support than the flipped classroom students did. While some studies show that no young students benefit from homework because of their lack of developed self-efficacy and metacognition (Hattie, 2010), other studies have instead found that students' socioeconomical background is an impactful indicator of how much students profit from homework, as the available resources to support their tasks at home can vary a lot (Nilsen & Bergem, 2015). In both arguments, the point is that the work students are expected to complete at home often requires too much mental effort from the students, making them rely on support from adults. Bloom's taxonomy tells us that students learn more from tasks that require a higher order of thinking, which are often tasks that require more effort (Anderson & Krathwohl, 2001). As the flipped classroom seeks to give students the more passive tasks at home, it tries shifting the higher order thinking and higher effort tasks into the classroom, lifting some responsibility from parents or legal guardians by transferring to the teacher instead (Erbil & Kocabas, 2020, p. 2). The fact that more students got help from home in the traditional class could also imply that there is a difference between the working groups in this regard, and the students in the flipped classroom could have gotten a higher score if they got help from their parents or the internet to the same degree as the traditional classroom students did. This could also imply that the students in the traditional classroom had a more difficult time understanding or remembering the concepts for their homework, and therefore asked for more support than the flipped classroom students did.

Normally, if a student is sick or away from school for other reasons, teachers might give them homework as a way to "catch up". In these cases, the student has not participated in the knowledge obtaining phase in the topic, and may not be able to grasp the full understanding of their homework, which further increases the necessity of support from parents or other resources to complete their tasks. This expectation for self-regulated learning from primary school students is something research has found probably cannot be met, as students this young haven’t developed this skill sufficiently (Loizou & Lee, 2020, p. 2). In a flipped classroom scenario, students can receive their input at home, meaning that when they get back to school, they have not missed the content, but rather the application of it. This is arguably better than trying to apply knowledge one did not obtain in the first place.

5.4 Design and Method reflection

5.4.1 Critical assessment of the teaching design

While discussing the different findings and implications of the study, it is also important to look into the method. The method has to be designed in a way that it is researching what is intended for the study, and it is therefore important to discuss to what degree it achieved its purpose. I made the decision in this study to give one student group more time than the other, in order to keep the content as identical as possible, limiting my ability to let bias affect the design. This decision made a big impact on how one has to read the results gained from comparing the teaching methods. The results could no longer be the sole indicator of how effective either of the teaching methods were, as one now also had to weigh in how much the difference in time spent could have affected the final verdict. This is not something that is easily measured, and other measures such as the questionnaire and older studies had to be brought in for consideration as well.

What was good about this decision, was that I limited how many parts I had to focus my attention on, as I have mentioned in earlier chapters. I could focus on the differences in one part of the teaching, and collect data more on how this differed between teaching methods. What was however not as thought through on this part, was that the design of the homework made it so the flipped classroom students got the same task to do at home as the traditional students, in addition to the video lecture. This goes against the purpose of changing the traditional homework design, and left this part of the difference between teaching methods to not be included. To uphold the argument of limiting bias in the design, while also tackling the issue of giving a more fleshed-out comparison of teaching methods, one idea could be to change the homework. If the task was more interactive or demanding of the students, it could have contained enough content that the flipped classroom students would have been able to spend time at school doing this instead. This would make sure both teaching methods were given the same amount of time at school, while still teaching them equal amounts of content. This way, one could also include another argument for flipped classroom teaching, that it allows students to be supported by the teacher while conducting their tasks that normally are done at home.

5.4.2 Using mind maps for assessing conceptual knowledge development

As the intention of this study was to look at how a teaching method impacted developed conceptual knowledge, it was important to find an appropriate tool for measuring this. In the method of this study, it was decided that mind maps would be used as the main tool of assessment, as they could be considered visual maps of knowledge. To measure conceptual knowledge, mind maps must be able to consider the different aspects involved in conceptual knowledge, so that they can create a complete assessment. In chapter 2.2 I presented how conceptual involved both the understanding of an idea or a concept, as well as the connections found between ideas to create a network (Watson et al., 2016, p. 119).

When looking at mind maps, one can see a lot of similarities between their description and the description I just mentioned above, and this is found even more when talking about scientific conceptual knowledge. In the theory chapter I mentioned how Wenham (2005) divided scientific knowledge into three different kinds of knowledge, and I will present how I think the production of mind maps could involve all these knowledge types. The first component was knowledge ‘what’, which involved the possession of factual knowledge and information (Wenham, 2005, p. 2). As stated in chapter 2.2.2, one could compare knowledge ‘what’ to the concept links found closer to the centre or to the top of a mind map. These can indicate what parts of a concept or topic a student is aware of, and sets the foundation for how they can display the deeper understanding they possess or develop. The next component was knowledge ‘why’, which is what one would see more of when going further away from the centre of the mind map. Knowledge ‘why’ requires a higher order of thinking, as the students are connecting concepts and explanations together. To observe this kind of knowledge in a mind map, one has to look at how the students have connected their concept links, and in what ranks of hierarchy they have put their different points. Usually in a mind map, it starts off with broader terms in the centre, and it branches out into more specific points as it expands. The connections between concept links are therefore important to create categories and connections that make sense, similarly to how they have to know what is related or not in different concepts.

While creating mind maps, the students are also showing their knowledge ‘how to’, as their mind maps’ structures, hierarchies, and categories are all factors that show to what extent a student is aware of the purpose of a mind map. If a student connects all their concept links to the centre of the mind map, as seen in Figure 13, the student is showing their possessed knowledge ‘what’, but they lack the awareness of the mind mapping potential to know that they are not properly displaying their knowledge ‘why’. The mind map assessment rubric is a tool that has tried to keep this in mind by rewarding not only what concept links the students used, but also how they were structured, and what connections were found between the concept links (Evrekli et al., 2010). Another dimension to mind maps that is also important to keep in mind is the quality of the concept links, which is one weakness of the MMAR. Baroody et.al. (2007) pointed out that it is not only the quality of the connections between concepts that matter, but the quality as well, to make sure the knowledge does not become superficial. While the MMAR does not directly score based on the content of concept links, it does imply that concept links of a higher level contain more advanced information and knowledge, as they have to go through multiple connections of previous concepts.

5.5 Considerations for the future

Here, I will discuss what should be considered in future studies. Firstly, we could note the sample size. This was a case study, that had a fairly small sample size, which limits the generalisation of these findings. This is because, with small sample sizes, any small differences between students have a much bigger impact on the results (Field, 2009, p. 35). Having only one class per teaching method also threatened the validity of the results provided by the questionnaire, as it is possible it merely displayed the differences between the classes, instead of the teaching methods. The students only participated in the study for one or two school sessions, and therefore did not provide a lot of observable data outside of the mind maps or the questionnaire. There also was not any pre/post-test conducted, so we could not know if there was a difference in the students’ general development or maturity before the study was conducted. The validity of the questionnaire was also limited by the fact that the students might not have answered everything honestly. As mentioned in chapter 3.5.3, there were some observations made that implied not all students answered truthfully. This may have been done to appear like a “better” student to the researcher, or simply from a lack of interest, but as the questions were only yes/no answers, investigating this any deeper would be difficult. This is not an uncommon problem with young students, as without knowing, while trying to help the researcher, they actually end up making their answers less reliable and less reflecting on the truth. I did state that the questionnaire was anonymous, and that I would not be offended if anyone said they did not do their homework, as a preventative measure to get them to answer truthfully, but some students still ticked off under “yes” instantly as they were given the questionnaire. If the questions were not simply yes/no questions, then perhaps this could have been less prominent, as this form of questioning could lead the students to feel like there are negative connotations to answering “no” to something.

For future recreations of this study, I would recommend having a larger sample size, including approximately three to four more classes for each teaching method. This way there would be a greater buffer for small inaccuracies and differences between each student, and the questionnaire would be able to provide data that reflected the teaching method, without risking negative impacts on the data due to class differences. Alternatively, if the sample size was kept to a similar size, the students could be given a questionnaire before and after the study, and include a more detailed questionnaire with questions regarding the students’ feedback on the video, as well as possibly some questions on their motivation in the subject similarly to Erbil and Kocabas’ study (2020).

I previously stated how I did not spend any more time creating the video than I did planning the physical lecture. An argument for using the flipped classroom was that the students found the videos to be more interesting to watch than reading books, and this could affect how much they paid attention while watching them. As I am no filmmaker, the video the students watched in this study turned out to be a simple lecture containing a PowerPoint, a video of me speaking, and pictures and gifs to give a visual representation of what I was talking about. This was not very different from what the students in the traditional classroom received, and one might argue that the method was therefore not used to its full potential. It was decided I would be the creator of the video, to make sure the two teaching methods received the same content, but perhaps using a more visually pleasing video, with interesting interactions and experiments, or perhaps an animation would have been better at catching the students’ interest. In Askedal’s study, the students responded that the quality of the videos heavily affected their motivation to watch and complete their at-home tasks (Askedal, 2016, p. 63). In hindsight it could have been useful to include what the students felt about the video in my own questionnaire as well, to see if their interest could have affected their mind map scores.

An improvement that could have been made to the design of the flipped classroom method in future studies would have been to make the at-home work more interactive. When the students are watching their videos, they are already connected to the internet, and it would have been a good idea to use this as an advantage. The students could have for example gotten the task of going on a “treasure hunt” on the world wide web, where they would have to seek out a picture or website related to the topic. If the students had to find one or two acidic or basic substances, they could have then been asked to insert their objects into the acidity gradient that they created in the activity. This would let them use their gained knowledge to try and discuss in what order of acidity they would be arranged, and why. If it was too difficult for them, they could place it somewhere, and look up how they performed compared to the correct order.

6 Conclusion and outlook

The aim of this study was to explore how flipped classroom teaching could impact primary students' development of conceptual knowledge in science education. Looking into the collected findings and the presented theory, the study implies that the flipped classroom method could be beneficial for students' conceptual knowledge development. The development of conceptual knowledge does not only come from acquiring theoretical information, but also from applying and understanding this information in different situations (Jensen et al., 2015, p. 2). This substantiates the importance of utilising practical work for this type of development, and as one of the main purposes of flipped classroom teaching is to leave more room for practical work, this can in turn imply that the flipped classroom also benefits conceptual knowledge development.

The findings of the study also imply that flipped classroom teaching could be considered more efficient for the school and for the students, in terms of time and effort, compared to traditional classroom teaching. While the scores of the two teaching methods had an insignificant difference between them, the traditional teaching still spent an additional school lecture to produce the same results as the flipped teaching. This showed that the short introductory video in the flipped classroom method was able to give sufficient knowledge to prepare the students for their next session, to the same degree as the longer introductory lecture in the traditional classroom method, which saved time that could be spent doing something else. The theory presented also implies that the flipped classroom method could counteract how much students' development from conventional homework is dependent on their socioeconomic backgrounds, as the teaching method has the students perform low-effort tasks outside of school hours, leaving more of the responsibility to help onto the teacher instead of a parent or legal guardian.

This project is merely a drop in the sea of research that is done, and that will be done in the future, but I would like to think it still provided some useful insight into how this can be developed further. It is easy to think that having an insignificant difference between results could mean that nothing was achieved in a study. However, as shown in this study, when looking into the different factors of the case, and looking at the findings up against the theory, this was not the case. In the end, the insignificant difference was able to produce multiple significant results, implications, and ideas, which led me to the conclusion I have presented for you here.

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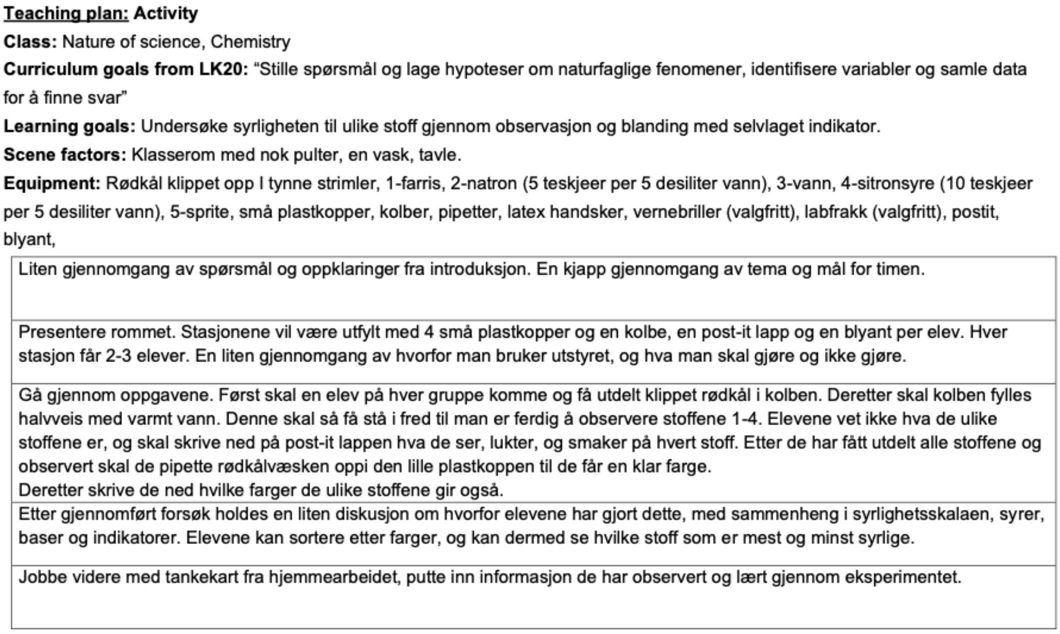
Attachments

***Attachment 1:** Lesson plan for the activity.*



<u>Teaching plan:</u> Activity

Class: Nature of science, Chemistry

Curriculum goals from LK20: "Stille spørsmål og lage hypoteser om naturfaglige fenomener, identifisere variabler og samle data for å finne svar"

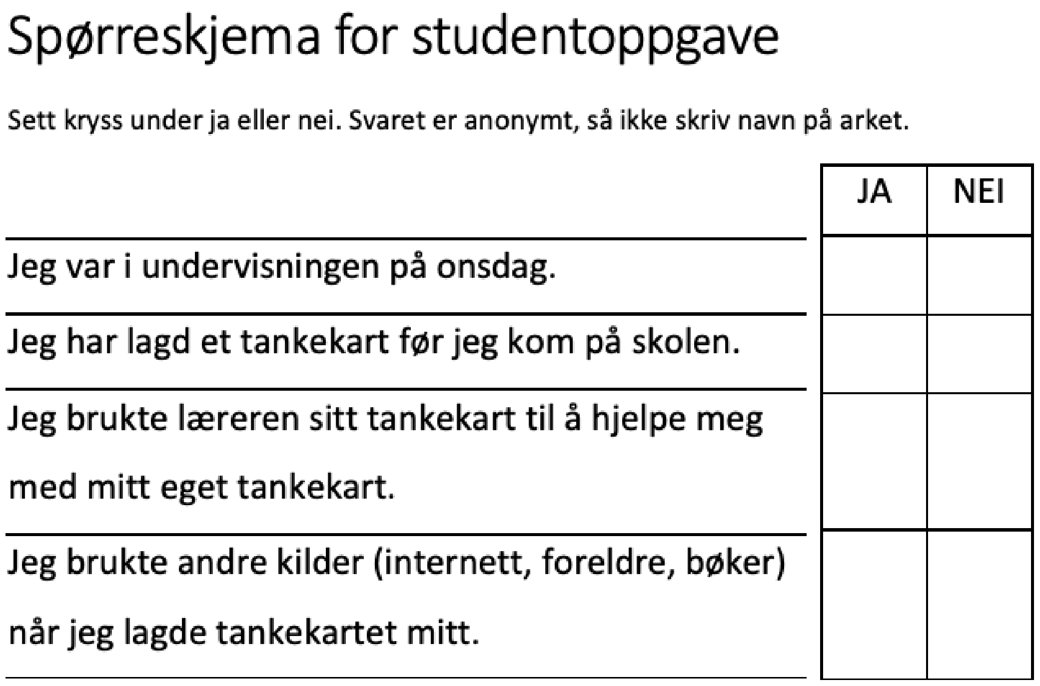
Learning goals: Undersøke syrligheten til ulike stoff gjennom observasjon og blanding med selvlaget indikator.

Scene factors: Klasserom med nok pulter, en vask, tavle.

Equipment: Rødkål klippet opp I tynne strimler, 1-farris, 2-natron (5 teskjeer per 5 desiliter vann), 3-vann, 4-sitronsyre (10 teskjeer per 5 desiliter vann), 5-sprite, små plastkopper, kolber, pipetter, latex handsker, vernebriller (valgfritt), labfrakk (valgfritt), postit, blyant,

Liten gjennomgang av spørsmål og oppklaringer fra introduksjon. En kjapp gjennomgang av tema og mål for timen.
Presentere rommet. Stasjonene vil være utfylt med 4 små plastkopper og en kolbe, en post-it lapp og en blyant per elev. Hver stasjon får 2-3 elever. En liten gjennomgang av hvorfor man bruker utstyret, og hva man skal gjøre og ikke gjøre.
Gå gjennom oppgavene. Først skal en elev på hver gruppe komme og få utdelt klippet rødkål i kolben. Deretter skal kolben fylles halvveis med varmt vann. Denne skal så få stå i fred til man er ferdig å observere stoffene 1-4. Elevene vet ikke hva de ulike stoffene er, og skal skrive ned på post-it lappen hva de ser, lukter, og smaker på hvert stoff. Etter de har fått utdelt alle stoffene og observert skal de pipette rødkålvæsken oppi den lille plastkoppen til de får en klar farge. Deretter skrive de ned hvilke farger de ulike stoffene gir også.
Etter gjennomført forsøk holdes en liten diskusjon om hvorfor elevene har gjort dette, med sammenheng i syrlighetsskalaen, syrer, baser og indikatorer. Elevene kan sortere etter farger, og kan dermed se hvilke stoff som er mest og minst syrlige.
Jobbe videre med tankekart fra hjemmearbeidet, putte inn informasjon de har observert og lært gjennom eksperimentet.

Attachment 2: *Questionnaire for the traditional classroom group.*

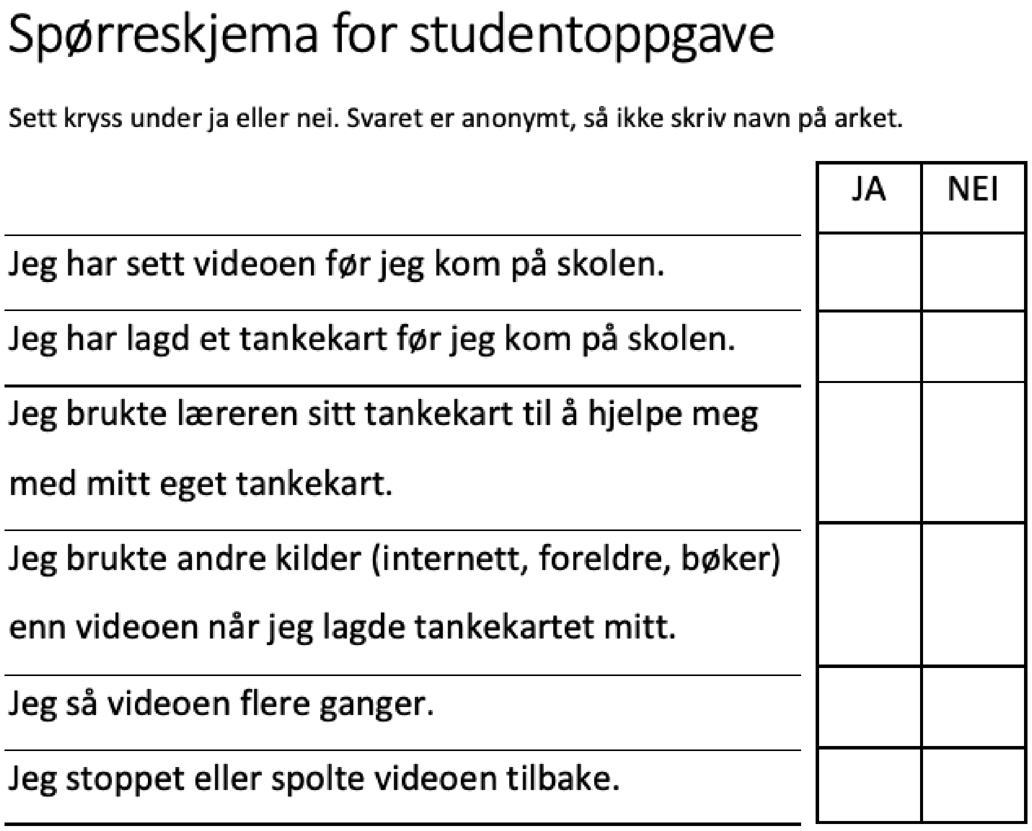


Spørreskjema for studentoppgave

Sett kryss under ja eller nei. Svaret er anonymt, så ikke skriv navn på arket.

	JA	NEI
Jeg var i undervisningen på onsdag.		
Jeg har lagd et tankekart før jeg kom på skolen.		
Jeg brukte læreren sitt tankekart til å hjelpe meg med mitt eget tankekart.		
Jeg brukte andre kilder (internett, foreldre, bøker) når jeg lagde tankekartet mitt.		

Attachment 3: *Questionnaire for the flipped classroom group.*

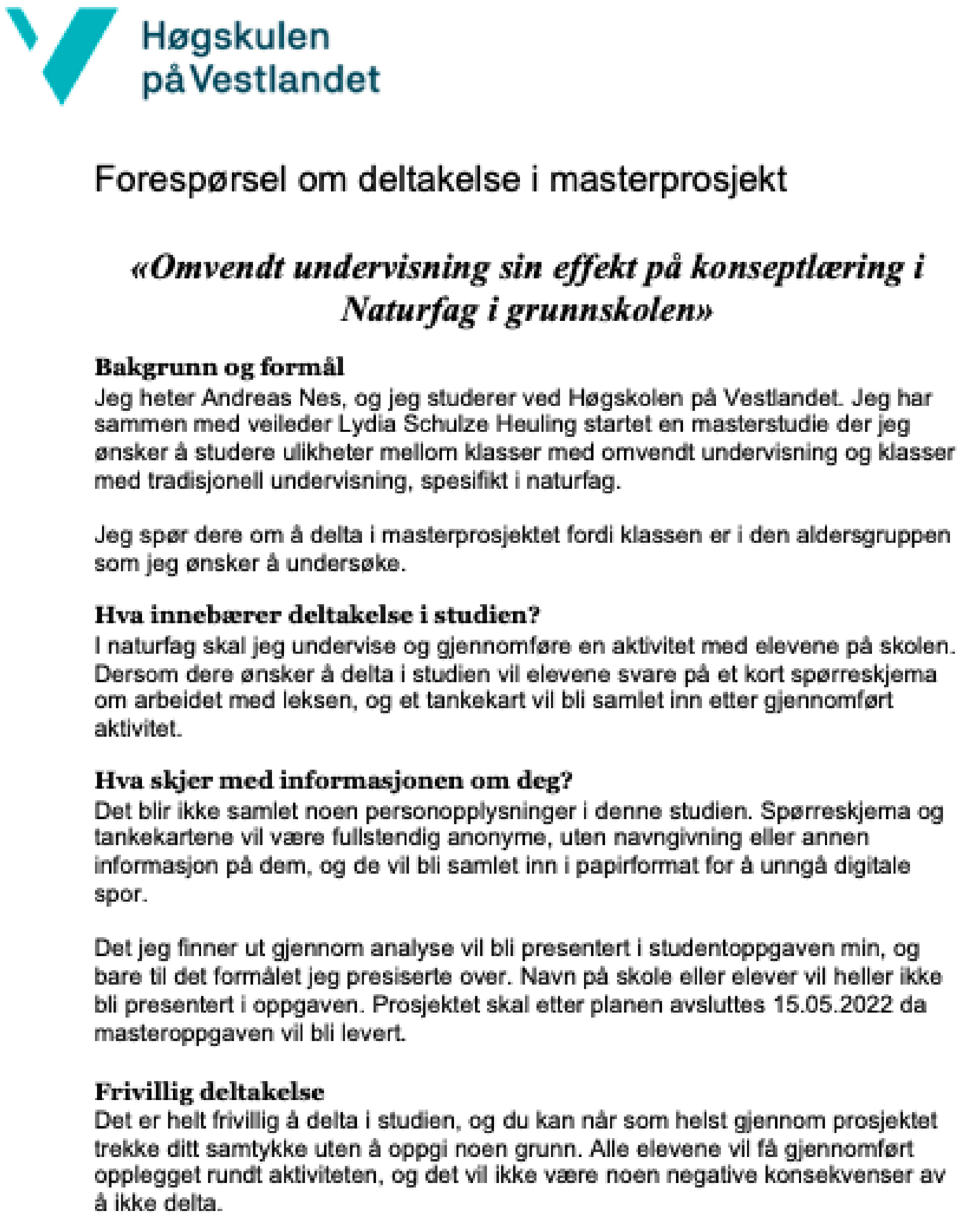


Spørreskjema for studentoppgave

Sett kryss under ja eller nei. Svaret er anonymt, så ikke skriv navn på arket.

	JA	NEI
Jeg har sett videoen før jeg kom på skolen.		
Jeg har lagd et tankekart før jeg kom på skolen.		
Jeg brukte læreren sitt tankekart til å hjelpe meg med mitt eget tankekart.		
Jeg brukte andre kilder (internett, foreldre, bøker) enn videoen når jeg lagde tankekartet mitt.		
Jeg så videoen flere ganger.		
Jeg stoppet eller spolte videoen tilbake.		

***Attachment 4:** Consent form given to the parents of the traditional classroom group.*



Høgskulen
på Vestlandet

Forespørsel om deltakelse i masterprosjekt

«Omvendt undervisning sin effekt på konseptlæring i Naturfag i grunnskolen»

Bakgrunn og formål

Jeg heter Andreas Nes, og jeg studerer ved Høgskolen på Vestlandet. Jeg har sammen med veileder Lydia Schulze Heuling startet en masterstudie der jeg ønsker å studere ulikheter mellom klasser med omvendt undervisning og klasser med tradisjonell undervisning, spesifikt i naturfag.

Jeg spør dere om å delta i masterprosjektet fordi klassen er i den aldersgruppen som jeg ønsker å undersøke.

Hva innebærer deltakelse i studien?

I naturfag skal jeg undervise og gjennomføre en aktivitet med elevene på skolen. Dersom dere ønsker å delta i studien vil elevene svare på et kort spørreskjema om arbeidet med leksen, og et tankekart vil bli samlet inn etter gjennomført aktivitet.

Hva skjer med informasjonen om deg?

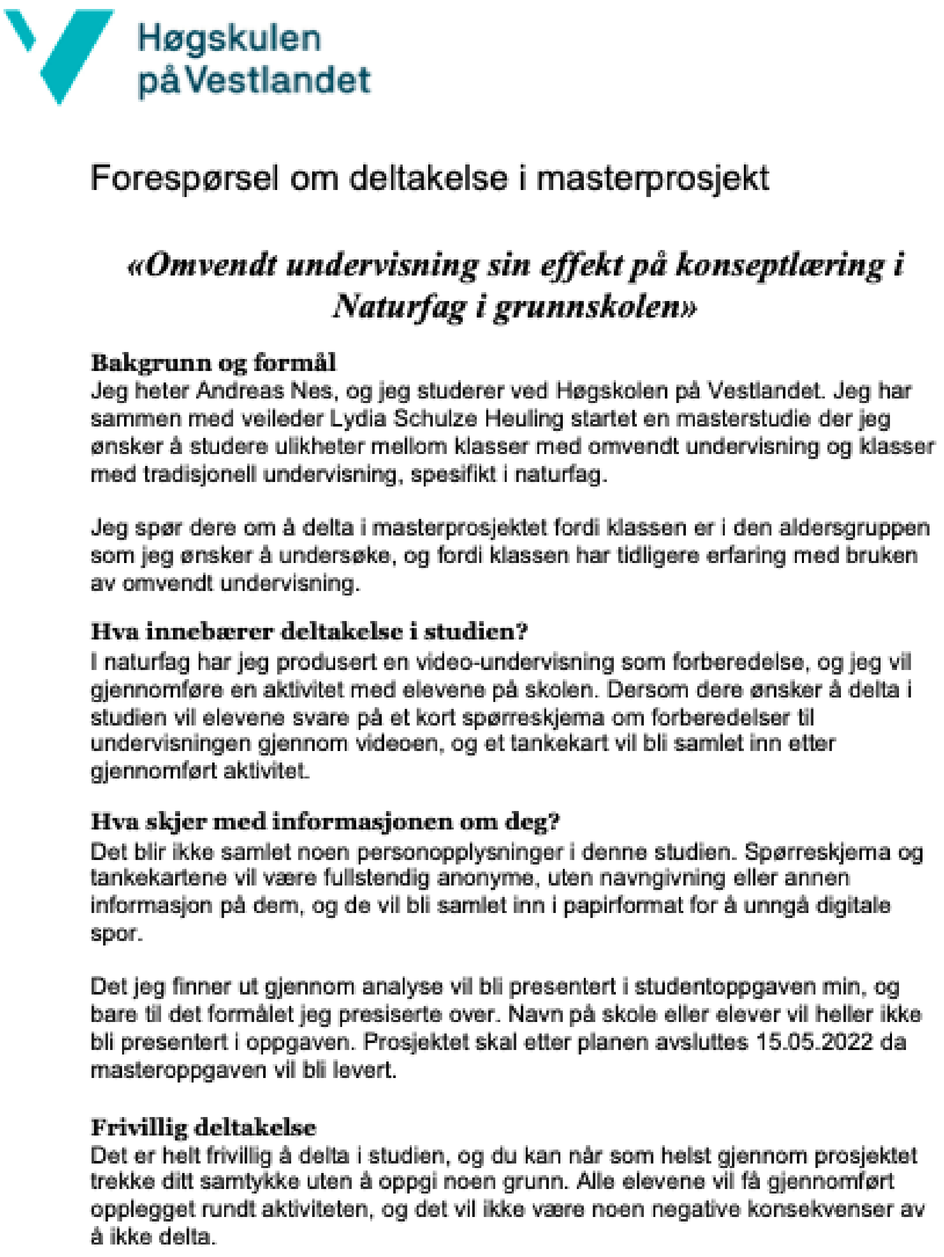
Det blir ikke samlet noen personopplysninger i denne studien. Spørreskjema og tankekartene vil være fullstendig anonyme, uten navngivning eller annen informasjon på dem, og de vil bli samlet inn i papirformat for å unngå digitale spor.

Det jeg finner ut gjennom analyse vil bli presentert i studentoppgaven min, og bare til det formålet jeg presiserte over. Navn på skole eller elever vil heller ikke bli presentert i oppgaven. Prosjektet skal etter planen avsluttes 15.05.2022 da masteroppgaven vil bli levert.

Frivillig deltakelse

Det er helt frivillig å delta i studien, og du kan når som helst gjennom prosjektet trekke ditt samtykke uten å oppgi noen grunn. Alle elevene vil få gjennomført opplegget rundt aktiviteten, og det vil ikke være noen negative konsekvenser av å ikke delta.

Attachment 5: *Consent form given to the parents of the flipped classroom group.*



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Jeg spør dere om å delta i masterprosjektet fordi klassen er i den aldersgruppen som jeg ønsker å undersøke, og fordi klassen har tidligere erfaring med bruken av omvendt undervisning.

Hva innebærer deltakelse i studien?

I naturfag har jeg produsert en video-undervisning som forberedelse, og jeg vil gjennomføre en aktivitet med elevene på skolen. Dersom dere ønsker å delta i studien vil elevene svare på et kort spørreskjema om forberedelser til undervisningen gjennom videoen, og et tankekart vil bli samlet inn etter gjennomført aktivitet.

Hva skjer med informasjonen om deg?

Det blir ikke samlet noen personopplysninger i denne studien. Spørreskjema og tankekartene vil være fullstendig anonyme, uten navngivning eller annen informasjon på dem, og de vil bli samlet inn i papirformat for å unngå digitale spor.

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