UiT The Arctic University of Norway

Faculty of Science and Technology

Department of Physics and Technology

How much are you able to make your students learn?

A study of the knowledge gain of students with high learning potential in the course of a teaching setup on wireless communication.

Amanda E. V. Gitlesen

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Abstract

This master thesis presents looks into how much knowledge can with high learning potential student gain from a tailored teacher setup. An tailored teaching program was created within the theme wireless communication and the data was collected mainly form an anonymous pre and post-test from four diffident subject groups from which the knowledge gain value g was calculated. The knowledge gain takes into account the students prior knowledge on the subject into the calculation. To have an indication of the basis behind the result of the knowledge gain value was a survey given to one of the subject groups to gain the students perspective on the teaching setup in addition to an written after action log in the aftermath for all the subject groups. The teaching setup itself had elements form both traditional teaching method and hands on guided activities for the students, but where the students own interest, comments and questions lead the discussions in different directions. The results of the calculation of the knowledge gain gave a value $g_{\text{ave}} = 0.41$ and according to the students themselves was the teaching setup educative, relevant and at an academic level which was neither to high or to low. The students own interests lead the implementation of the teaching setup in slightly different directions, which could not be predicted into the predetermined goals and questions for the pre- and post-test, where the exactly the same test was used on all of the subject groups. Thereby gives the knowledge gain value only an indication of partly how much the students truly has learned, but is the closest one can get to a measurement of the students knowledge gain.

I want to thank the Talent Centers connected to Tromsø and all its participants for letting me hijack their first assembly of the year, my supervisor Felix C. Geisler for making the finish line feel achievable even as you added more work to be done, and last but not least my parents for lending support and willing to listen whenever I need to talk

Table of Content

List of Figures

List of Tables

1 Introduction

1.1 Background and aim

A teacher's main task is to help their students to become good citizens by developing the student's competence and knowledge. However, all students are unique and absorb knowledge differently, and some students learn faster than others. In general, the education system aim to avoid student classification and instead promote an idea of development for all its students [1]. At the same time, the term adaptive education has a profound impact on the Norwegian education system and is visible in different policy documents since the 1980s [2]. Specifically, the Norwegian Act relating to Primary and Secondary Education and Training (the Education Act) section §1-3 Adapted education states that:

> *«Education must be adapted to the abilities and aptitudes of the individual pupil, apprentice, candidate for certificate of practice and training candidate.»* [[3], §1-3]

This means that every student, irrespective of a student's prerequisites, such as gender, cognitive ability, impairments, disability or learning potential, has a right to have their needs to be taken into account. Thereby, some level of classification of the students are needed. From the author's experience and observations, the school is often very good at considering its "weaker" students, the students that need extra help for some particular reason. But what about the other side of the spectrum? The students who are talented or gifted in one or more subjects and might learn faster than their peers who do not have the same educational adaptation. These students are often called students with high learning potential. Historically, there has been minimal extra focus on these students [1] due to the understanding that this group manages itself and will do well regardless. Nevertheless, it is estimated that about 1/3 of the students who drop out and do not finishes their high school education are students that have a high learning potential [4]. For society, this is a loss of a considerable resource in future idea and achievement potential which could help build the community. One of the reasons these students might drop out is that they do not get the adaptation in their education they need and end up so frustrated that they give up in the end. The Talent Center has been developed at several Science Centers in Norway to focus on these students with high learning potential and an interest in science, in the hope to create a extra resource in addition to the standard school education to motivate and challenge the students to continue their education.

It is very likely that every teacher will at one point, come into contact with the whole range of the learning ability spectrum. As of today, in teacher education, it is discussed how to set up the teaching for the weakest students, but there are in principle no discussions about the talented students. However, this is in the process of changing [5]. The author came into contact with a talented student during the practical part of their studies. A student in their mathematics class got more and more frustrated by the pace and level of difficulty, which was so easy for the student to a point where the student was ready to throw the book at the wall [6]. Much time was set aside to find ways and activities to keep the student engaged, active and focused during the lessons, which in turn positively affected the rest of the class. This student is partly the inspiration behind the subject of this master thesis.

1.2 Thesis question

We all spend several years of our life behind a students desk in the classroom, but how much do we truly learn? As a teacher, a lot of time is used to create and plan lessons and activities that engage the students and give them as much knowledge and understanding as possible. But, how much knowledge do the students gain from our teaching? This is the question that will be explored in this master thesis. More specific: how much knowledge gain can students with high learning potential acquire from a tailored teaching program?

Today in the 21st century we live in a digital society, where the children in Norway can use technology such as smart phones and computers from an early age. Around 87% of children in the age group 9-10 years in Norway already has their own phone [7] and digital technology has more and more become a part of the Norwegian classroom, where many primary schools already has started to use tablets as a part of the teaching setup [8]. Thereby, technology and digital communication highly relevant in toady's society and the theme set for the Talent Centres first assembly of the year and the thesis question for this master then becomes: **"How much knowledge gain can students with high learning potential acquire from a tailored teaching program within the theme wireless communication?"**

1.3 Previous research

There have been several different studies into knowledge gain and learning outcomes in previous years. In the 1990's Richer R. Hake did a six-thousand-student study on knowledge gain of traditional teaching verses the use of an interactive engagement method [9]. The study indicate that the student's average knowledge gain values around $g_{\mathrm{T}} \approx 0.23$ for traditional teaching and $g_{\mathrm{IE}} \approx 0.48$ for interactive engagement. None of the classes analysed in Hakes study averaged a knowledge gain of over 0.7. Furtak et al. in 2012, analysed 37 studies from 22 different papers on the effect size of inquiry-based teaching and reported it to be around 0.50 [10, 11]. What the results form earlier research means for this mater thesis, in practice, is to create a single teaching program tailored to the students and try to achieve a value of the knowledge gain as close to 0.5 as possible.

There has also been several other researches into the correlation between inquiry-based teaching, learning outcome and the student's motivation, which mostly shows a positive correlation [11, 12]. *«A study into the PISA 2006-data showed, on the other hand, that even if there was a positive correlation between frequency of inquiry-based teaching and learning outcome, where there was a focus on modelling and use, there was a negative correlation in hands-on dominated activities»* [Translated from Norwegian [11], p. 52]. This give an indication that a variation of teaching methods might be the most effective.

2 Theory

2.1 From Learning outcome to knowledge gain

Learning outcomes translated to "læringsutbytte" in Norwegian is a relatively new term in the Norwegian school system that shows up more and more and has gotten a central role since the 2000s [13]. At first glance, the term can seem self-explanatory and straightforward, especially in English. Still, interestingly in Norwegian, the term is not as clear, and linguistically gives the word itself associations that can point in several directions. In addition, the interpretation of learning outcome provides the concept with different content depending on the context, whom (researchers, politicians, school leaders or teachers), and the situation the term is used [13, 14]. Thereby has learning outcomes several different definitions.

2.1.1 Some definitions and imputation of learning outcome

The Oxford Dictionary of Education defines learning outcomes the same way that objectives is defined.

> *«A clear statement of what the student or pupil should have learned by the end of the task, the lesson, the 'scheme' of work, or the course of study. Learning objectives provide focus and direction to clarify what must be assessed in order to ascertain whether learning has taken place...»* [[15],[13], p.18].

This limits the concept of the term to have a focus on the end result of learning. This focus follows the definition on leaning outcome used by the Norwegian school system. The following definitions shows how the concept is defined in the Norwegian education policy:

The Norwegian Qualifications Framework for Lifelong Learning
In the Norwegian Qualifications Framework for Lifelong Learning (NQF) is learning outcome definite much the same as the definition from the European Qualifications Framework (EQF), which defines learning outcomes as:

> *«...statements regarding what a learner knows, understands and is able to do on completion of a learning process, which are defined in terms of knowledge, skills and responsibility and autonomy.»* [16]

The National Organ for Quality in Education
The National Organ for Quality in Education (NOKUT) defines learning outcomes much the same as NQF and EQF, but adds that *«learning outcome must be measurable.»* [[14], p.10]

The Norwegian Directorate for Education and Training
The Directorate for Education and Training (NDE) is a sub-body of the Norwegian Ministry of Education and is responsible for developing the school sector and implementing the education policies [17]. On the NDE web page, learning outcome is defined as what the individual has learned and can perform after completing the schooling [18].

These examples of learning outcome definitions all have a clear focus on the end result of the learning process. Since this are the definition used in government documents and education policy's, it can be defined as the official definitions [14] of learning outcome. The focus on the end result in the definitions have been strengthened after implementing international and national assessments for quality development, such as the Program for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMMS), which has led to a stronger learning-outcome approach in the education system world wide, including in Norway, since education reform in the 2000s after "the below-average PISA result" of 2001 [19].

Even if the current definitions is used in education policies, it does not mean that it is unambiguously interpreted, which is something that the definitions take for granted [19]. In truth, there are several different ways to interpret learning outcomes both as term and concept, which creates several approaches to learning itself, teaching and assessment. There exists a numerous other examples where the idea is interpreted more toward the process of learning or education and not so much focus on just the end result [[13], p.27]. In these interpretations learning outcome emphasises the work connected to teaching or as a tool to help with planning, implementation and documentation of the learning-based goals and this is the interpretation most often used in scholarly debates. Elliot Eisner, a professor of Art and Education at the Stanford Graduate School of Education, strongly criticised the objective orientation in education in the mid-1960s, which is used as the definition of learning outcome in education policy today [19]. Eisner considered it nearly impossible to predict the total learning outcome as a directly measurable down written goal [13]. Instead, he saw the learning outcome as a learning process divided into three types [13, 14]:

- *Student specified* learning outcome corresponds to what the students have learned, which includes knowledge, skills and attitudes and is not directly connected to the material that is being taught, but the students own capabilities. Just as important is the the learning that arise from the students own interest in the subject matter, where it stimulates the student to learn material the might just boarder to the subjects content. According to ROSE study, The Relevance of Science Education, are boys generally more interested in technology than girls, who shows a higher interest in themes that related to the living world such as medicine [[20], p. 100-106].

- *Subject specified* learning outcome is the knowledge gain and skills directly related to the material and subject content. This corresponds well to the official definition of learning outcome, but it doesn't necessarily have to match the present goals of the lesson, which gives it a wider approach than the definitions itself.

- *Teacher specified* leaning outcome indicate the students learning outcome that is gained from the teachers own capabilities, standards and values. The teachers values, who he or she is, what the individual student think of their teacher and what is being emphasized has a vital importance on the students learning outcome.

In Eisner's opinion, the three elements are vital to a student's total learning outcome, as indicated by the star (*) in the illustration given figure 1. Since a student's learning outcome is affected by several factors, the student's own capabilities, the teacher and the subject matter will predetermine down written goals looses nearly all meaning [13]. It might not even be desirable to predefined all learning, since so mush of the most valuable learning taken part outside of what is predefined and planned. Eisner on the other hand do not discard learning outcome as a concept, just the interpretation that it directly can be connected to predetermined goals and the interpretation of the

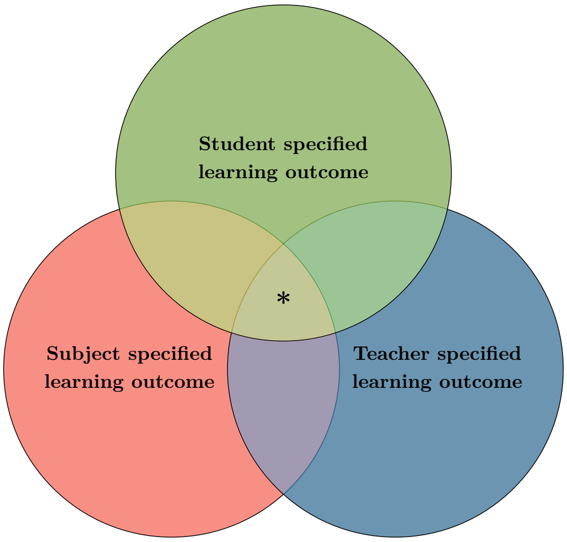


Figure 1: An illustration of the three elements vital to a student's total learning outcome [[13], p. 42]

leaning following this. In the end is learning outcome is defined according to Eisner as; *the learning outcome the student gain in the end after a learning activity, intentional or not* [[13], p. 42-43]

2.1.2 Knowledge gain

Acquiring a measurement of a student's learning outcome x_{post} is not a trivial question. Specifically, the students *knowledge gain* will be measured, as how much knowledge the student has gained throughout a lesson. A student with no prior knowledge of a subject will show a higher knowledge gain to an observer compared to a student with more prior subject knowledge. Thereby, in trying to set a more accurate value of the knowledge gain, the student's prior knowledge of the subject x_{pre} must be considered. In the calculation of the knowledge gain, the student's prior knowledge will be measured as the correct answer response rate through a pre-test, where the correct answer response rate will be set as a real value x_{pre} between 0 and 1. The same questions as in the pre-test will also be used in a post-test to test the student's post knowledge, given after the lesson completion, where the correct answer response rate from the post-test gives a real value x_{post}, which also measures between 0 and 1.

The objective is to lift the student's up to a complete understanding based on prior knowledge, which corresponds to a value $x_{\text{post}} = 1$ and the best case scenario. Still, the post-test by itself does not give an indication of the knowledge the student gained and thereby doesn't tell us how much the student has truly learned from the lesson itself. To get an indication of the actual knowledge gain from the lesson, the achieved knowledge gain, $x_{\text{post}} - x_{\text{pre}}$ is defined, how mush the student has gained from the lesson itself, in relation to the maximal knowledge gain $1 - x_{\text{pre}}$, (the greatest possible for learning growth for the student in accordance with the students prior knowledge). Thereby, the knowledge gain g can be calculates as equation 1.

$$g = \frac{x_{\text{post}} - x_{\text{pre}}}{1 - x_{\text{pre}}} \tag{1}$$

where g is a normalized value of the student's actual knowledge gain form the lesson or teaching setup, with a maximum value of $g_{\text{max}} = 1$.

2.2 High Learning Potential

High achieving students or students with special talents and students with the potential to achieve on the highest level are often called gifted, talented or over 100 more other terms in international reports [21]. Since an inquiry into this group of students in 2015 has the term students with high learning potential emerged in Norway, as this term covers the diversity and heterogeneity of this student group better.

The Directorate of Education define students with high learning potential as:

> *«students who learn faster and acquire more complex knowledge compared to peers»* [Translated from Norwegian, [22]]

To clarify, this term includes *«not only students who are already performing at a high and advanced level, but also students who have the potential to do so in one or more subjects»* [Translated from Norwegian, [22]]. It is estimated that students with high learning potential make up approximately $10-15\%$ of the student population [21]. Integrated into this value are also students with extraordinary learning potential, which make up about $2-5\%$ of the student population. Compared to a student with high learning potential, students with extraordinary learning potential show that they have good aptitudes or special abilities, and they often have an IQ of 130 or more. This doesn't mean that a student's learning potential is reflected directly in a student's grade or achievements [1]. Students with higher learning potential are just as a complex group as any other. They are just as different from each other as any other student group or class, with different individuals and personalities, which has differing instruction and development needs.

The term includes both the students that are already performing at a high and advanced level and those that have the potential to do the same. Even if students with high learning potential are quite heterogeneous groups, *«they can still be divided into two main groups: 1) the students with high learning potential and high level of achievement, 2) the students who have the potential to achieve at a high level with an unredeemed learning potential»* [Translated from Norwegian [1]]. The connection between learning potential and achievements are not crystal clear. Figure 2 indicates how the areas overlap and create different combinations. Historically, has nor there been a big focus on students with high learning potential due to the assumption that this group of student's manage on their own, and will perform good enough irrespective of educational approach. The reason a student achieve at a high level might be due to high learning potential (b), but it must not be overlooked that it is fully possible that the student has put in a lot of work into the subject to achieve the good grades in the area (B). There can also be students that have a high learning potential, but at the same time a unredeemed potential (c). This can be due to lack of adaptation which gives the students the opportunity to shine, or that the student might be bored to the point that they have given up. A student might have high learning potential, achieve at a high level but still has the potential to achieve more (D). For many of these students learning come easily and they do not acquire the best learning strategy and work habits, which make them work under their potential even as they achieve at a high level. Also, when these students meets resistance in a subject their achievements are often lower due to a lack of a good work ethics.

The school system has generally avoided to put labels on students, but with studies into this group it has been realised that these students learn in different ways, are often unrecognised or misdiagnosed and thereby do not get the adaptation of their education that are in their rights to according to the Act relating to Primary and Secondary Education and Training section §1-3 Adaptive eduaction [1]. There are many different types of studens with high learning potential and some are easier to identify that others. Betts and Neihart [23] has over several years of observation mapped different shades of talented students or students with high learning potential and categorized them as six different student types to further show the the diversity in this group of students. The six different types are; the "successful" (type 1), the "challenging" (type 2), the "underground" or "hidden" (type 3), the "dropout" (type 4), the "double-labeled" (type 5) and finally the "autonomous" (type 6). Identifying all these students is not always trivial [[24], p. 69]. The type of student that is easiest to identify in this group is type 1. These are the "successful" students who have generally broken the school code and are doing well in school. Type 6, the "autonomous" students are also students who do well in school and are generally easy to identify. But unlike the "successful", the "autonomous" students get the system to work more for them, than to work for the system as the "successful" do. This means that the autonomous students are often more creative than the successful ones who solve problems more slavishly according to the book and thereby can not as easily see the solution to the same type of problem presented in a different way. Creating autonomous students is something that the school generally strives for. The other student types are often a little more difficult to identify and these students often face some major challenges in the school system. Especially type 2 the "challenging" student, who often ends up in conflicts with adults such as teachers and are the students high learning potential often and easily

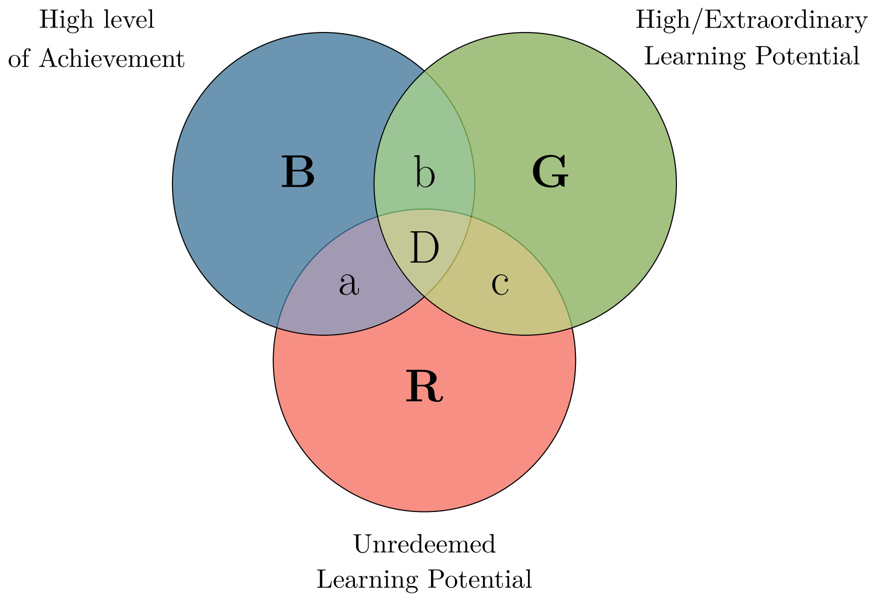


Figure 2: An illustration of correlation between learning potential and achievement in form of a Venn diagram. The blue circle (**B**) represents high level of achievements, the green circle (**G**) represents high learning potential and the red circle (**R**) represents unredeemed learning potential. *Illustration is inspired by* [[1], p. 17]

overlooked [23]. Type 3 are those students who tend to deny their great learning potential and perform below their level in the desire not to stand out from the norm in the class. The students who can be categorized as the "dropouts" or type 4, are the ones who may feel rejected from the school system and simply give up. One reason for this may be that the students are not sufficiently academically challenged and they get tired of repeating subject matter that they already have good understanding of. In this type of student, their great learning potential is sadly often discovered to late. The last student type, type 5 are the students who are double-classified. In addition to the great learning potential, these students also have a learning disability or diagnosis. Unfortunately, this group is particularly prone to misdiagnosis, as well as the fact that their great learning potential can be unidentified, due to the focus being largely put on their difficulties.

2.2.1 Talent Center

In 2015 the Norwegian government established a new education strategy with the focus on science subjects *"Tett på realfag"* [25], translated "Close to Science". One of the goals of the strategy is that, *«more children and young people will perform at a high and advanced level in science»* [Translated from Norwegian [25]]. It is estimated that about one third of high schools drop-outs and do not finish their education, and approximately one third of these again are students with high learning potential. This is a large loss of a resource for the society, in futuristic ideas and achievements which could help build up the community [4]. Thereby in accordance to the science strategy goal and the Act relating to Primary and Secondary Education and Training section §1-3 Adaptive education four Science Centers including Tromsø was given an objective to create a meeting place and resource for students with high learning potential with an interests in science, named the Talent Center [**?**]. The Talent Center is by no mean a replacement for the school, but instead a supplement for the student if needed [4]. The focus of the Talent Center is to work on the development of motivation, interest, creativity, curiosity, endurance, etc. and to give students with high learning potential help the students to reach for their potential. The name Talent Center can be a bit misleading. Some are under the impression that the Talents Center is for the "elite" students and that it is wrong to give students this classification, since it can indicate the classification of "bad" students.

> *«Emphasized that being good at science is about much more than getting the right answer to the task. That's why its worrisome that at an early stage the students are put in a category, where it is said that one is good, while another is not. ... It is not always*

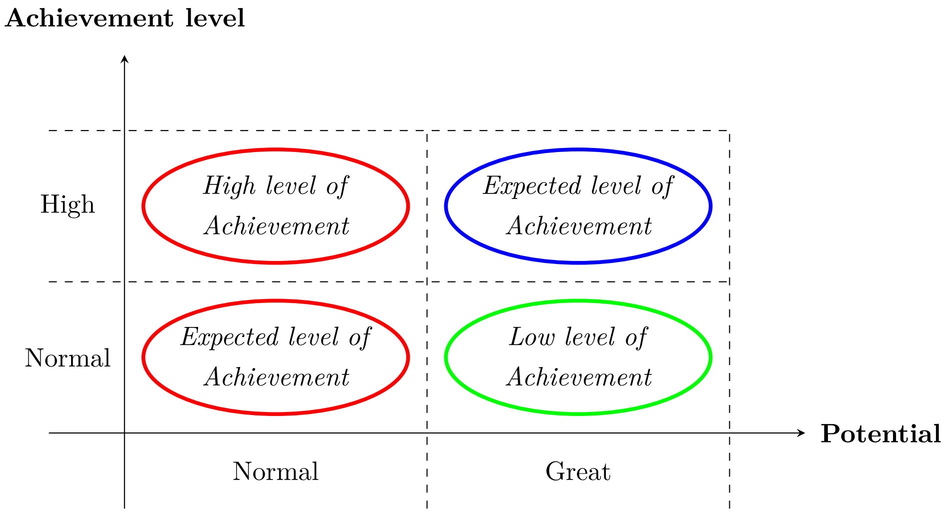


Figure 3: Students with great learning potential in the target groups for the Talent Center, inspired by [4]

> *the student who does best on tests, who has the greatest potential. It may just as well be the children who think a little differently and creatively»* Kjersti Wæge, researcher and center manager, National Center for Mathematics in Education at NTNU, translated from Norwegian [26].

In this way the name might be misgiving, since in truth the Talent Center is created for the students who might not do best on tests and who might think a little differently and creatively. The students that participate in the Talent Centre goes through a lengthy selection process, where the the Talent Centre categorise the students according to Betts and Neihart student types. The focus of the Talent Centre is to try to specifically capture students of type 3 and type 4. Talent Centre goal for these students is to create a safe arena, where the students will dare to take the chance to put themselves in the spotlight, with special focus on to type 3 students. Efforts are also made to create the academic challenges the students need to build on their established knowledge, with specific thoughts on type 4 students, but also to students in general. This means that the Talent Center is for the student that has the potential to achieve more and and not necessarily already achieve at the highest level, represented in figure 3

An evaluation of initiative in 2019 shows that the Talent Center has had a positive outcome on students with high learning potential and it became in 2019 a permanent establishment and today has been implemented in several of the science centers in Norway [27].

2.3 Teaching methods in science

2.3.1 Inquiry-based teaching versus traditional teaching

«There are a wide variety of instructional methods and strategies that can and are being used in the teaching of science, ranging from those that are more teacher-centred to those that are more student-centred» [[28] p. 314-315]. Few of the traditional instructional methods and strategies generally used in the teaching of science in schools are such as *demonstration, classroom explanations and questioning* [28, 29].

Demonstration
Demonstrations have always played a distinctive central role in the teaching of science. Demonstrations are often a less expensive and safer way to provide the students with visual confirmation of some of the concepts [28]. Traditionally, the demonstrations done by the teachers in the laboratory and classroom are often surprising, colourful, and dramatic, but this does not always serve the main goals of teaching such skills and concepts. However, it does help to motivate the students to learn and increase their interest and engagement in the subjects taught in the science classroom. As mentioned, does not these demonstrations necessarily help the students understand the concept

being taught as the teacher intended. This is because the student might lack the knowledge and theoretical background needed to grasp more than the surface feature to piece together more than only what they observe for the understanding. Demonstrations by the teachers also do not allow the students to test their own ideas and during a passive demonstration the students might lack the opportunity to ask their teachers questions. With the use of more and more technology in science teaching, computer-based simulation is being used more as a type of classroom demonstration. Computer-based simulations enable the students to experience the visualizing scientific phenomena that are all beyond human experiential limits and compare to an laboratory demonstration can it give the students the opportunity to try it out for themselves. *«Over the years, has much effort been made to design better classroom and laboratory demonstrations to address the shortcomings in various science disciplines* [[28], p. 305].

Explanation
In teaching of sciences has always both descriptions and explanation of scientific phenomenon been involved [28], where the teacher delivers the content to the students [10]. The descriptions provide the students with pieces of information, i.e. different facts or key knowledge, which can not always necessarily seen as directly related [[28], p. 306]. Explanations however connects the pieces of information together, to a broader the students understanding. Student often sees teacher explanation as the absolute truth and thereby doesn't try to make connections of their own. So apart form teachers own explanation, will teacher also encourage students to generate their own explanation with their peers or their teacher in plenum during class though discussions to depend the students understanding.

Questioning
Questions are deeply integrated int any teaching situation and has been a part of teaching and learning for all time both form the students and teachers. The dominant type of questioning used in the classroom is of the form of initiation-response-evaluation (IRE) or initiation-response-feedback (IRF), where the teacher ask questions and calls on the students to answer them [28] anfd when gotten the correct answer continues on. Over the past decades has research shown that this type of questioning during classroom teaching is often unproductive without giving the students sufficient time to think before answering [[28], p. 307]. Still, questioning is a valid tool for teachers and by using questioning to create a dialog in the classroom, which gives the student the opportunity to argue and justify their ideas and thoughts has studies shown that questioning is a very effective tool and especially in inquiry-based teaching. Questioning in the form of IRF has its place in the classroom where the teacher can use it as a tool when already established knowledge needs to emphasized.

Inquiry-based teaching has gotten more and more attention in science pedagogy research and the curriculum both in Norway and internationally [11]. But to try to find one definition hardly fruitful since there are several definitions around this method [30]. On the other hand the approach that is most often used to describe inquiry-based teaching is where the students draw upon their own scientific knowledge to ask scientific questions or create their own hypothesise, collect and analyse the evidence form scientific investigations or experiment's to develop their own explanations and scientific reasoning of the scientific phenomena, which is communicated to their teachers and peers [10, 31, 30]. This approach is a very student centred method with the teacher staying in the background and guide though questioning, while the student's engage in self-guided, hands-om activities [10]. The biggest critics against this approach is that a minimally teacher guided approach *«does not provide sufficient structure to help the students learn the important concepts and procedures of science»* [[10], p. 301]. The approach is in direct opposite of a teacher-led approach, represented in figure 4, which is often looked at as the traditional way of teaching. Traditional teacher-lead teaching is where the teacher delivers the content through carefully designed lectures and explanations, with verification-style in form of laboratory activities and demonstrations [10, 28]. The practical work and experiments is first given after the theory lecture in traditional teaching, where they most often are in the form of clearly structured "recipe" exercises [31]. Earlier research by for example Richer R. Hake [9] all indicated that inquiry-based teaching gives the students a higher learning outcome than traditional teaching, but in this studies wasn't always inquiry-based teaching so clear cut. The approaches looked upon until now is the on the opposite outer edges of the teaching spectrum in figure 4. There are several different method that falls in the expression of inquiry-based teaching that is not so clearly at the edge [30]. In this thesis will the middle ground be acknowledge in form of teacher-guided inquiry, where the teacher guide the students activities in a reform-oriented science lesson [[10], p. 306].

From earlier research such as Hake's study [9] on the knowledge gain of interactive engagement (*«methods that are designed at least in part to promote conceptual understanding though interactive engagements (IE) of students in heads-on (always) an hands-on usually activities which yield immediate feedback though discussion with per and/or instructor»* [[9]], p. 65]) versus traditional teaching (*«make use of little or no use of IE methods, relying on passive-student lectures, recipe labs and algorithmic-problem exams»* [[9]], p. 65]) showed that knowledge gain from an interactive method landed with a medium region (medium-g) of $0.3 \leq g < 0.7$ and in a low rage (low-g) $g < 0.3$ for traditional teaching [9]. None of the classes knowledge gain within Hake's study laden with in the high region (hing-g) of $g > 0.7$, but from the research its indicated that a more student-centred or student active approach is beneficial for the students knowledge growth, which will be kept in mind during the creation of the tailored teaching program in this master thesis.

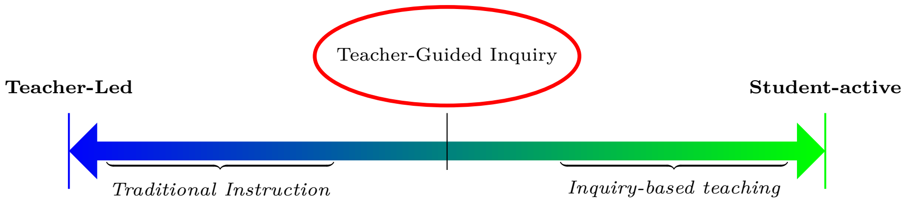


Figure 4: Guide to teacher/student activity in teaching reforms, inspired by [10].

2.3.2 STEAM education approach

STEAM education, a known predecessor to the newer acronym STEM education now i use, is a multi-discipline approach to teaching, where rather than teach the five disciplines in the acronym as separate and discrete subjects, STEAM integrates them into a cohesive learning paradigm repented in figure **??** based on real-world applications [32]. The acronym STEAM stands for Science, Technology, Engineering, Art and Mathematics. *«In some cases* STEAM *education reefers to the teaching of one or more of the constituent disciplines»* [[32], p. 32], but it can *«also refer to a interdisciplinary, multidisciplinary or integrated approach»* [[32], p. 32] in one or more of the subjects. In addition can STEM education *«be used as a label for approaches that emphasise the development of certain skills, such as problem solving or critical thinking»* [[32], p. 33]. In later years have the (A), which emphasised the creativity aspect in problem solving, have been left out of the acronym itself and has merged into together with (E). *«There is no formal definition of what knowledge in engineering (E) includes, but there is a growing consensus that it includes knowledge about design process, framework factors, criteria, optimization and balancing»* [Translated from Norwegian [33]]. In research around the effect on the STEM-model found Becker Park [34] in a evaluation of 28 different studies that there is a greater learning effect the earlier the integrated approach is implemented [33, 34]. Form their study can it be deduced that the STEM approach has an average effect size around 0.42 on a students grade for middle school students [34]. If integrated STEM teaching is to have a positive effect on learning and goal achievement, must students move back and forth between acquiring knowledge within each discipline and applying this knowledge in a multidisciplinary context [33]. Students must have competence in discipline-specific representation and be able to translate between the different representations. This is called "representational fluency". To participate in practices that are part of several disciplines, for example modeling in engineering, natural sciences and mathematics, can support such "fluency". The problem with creating this multidisciplinary context is that teachers often have limited competence within the STEM subjects. Many teachers do not have sufficient competence in their main area (only six of ten teachers which teach natural science have any study points in science in the Norwegian school system [[35], p. 59]), and they often have very little competence within the other STEM subjects than their main one [33]. It is therefore difficult to make integration explicit and facilitate adequate support for students when they need to see the connection between knowledge across several disciplines.

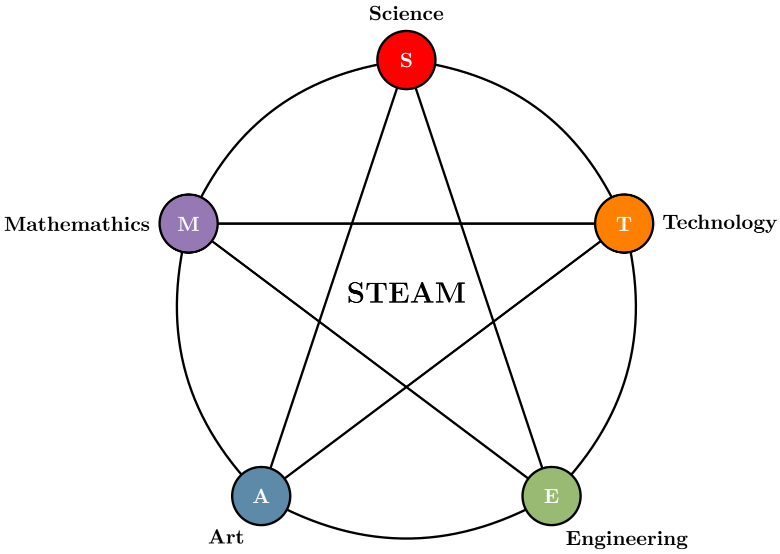


Figure 5: A visual illustration of the multi-discipline STEAM approach

The Talent Center assembly's are planed around the STEAM approach, as a multidisciplinary approach within the natural sciences, technology, engineering, programming and mathematics with the room to let the student's creativity in problem solving shine (A), which is one of the indicators of a student with high learning.

3 Method

3.1 Subject Group

In accordance with the thesis question to explore the knowledge gain in students with high learning potential, was students from the Talent Centers 2021/22 connected Science Center in Tromsø recruited. The data was collected from 4 different Talents center groups in total; Alta (A), Bodø (B), Tromsø A (TA) and Tromsø B (TB), where all the student's are in the 8-10 grade. The subject groups configuration is shown in table 1 with total number of participants $N_{tot} = 75$, where $N_B = 48$ are boys and $N_G = 21$ are girls.

Table 1: Subject group composition, with gender distribution

Subject Group	**Total number of students in the group**	**Gender distribution**	
Alta (A)	17	Boys	10
		Girls	1
Bodø (B)	17	Boys	12
		Girls	5
Tromsø A (TA)	20	Boys	10
		Girls	10
Tromsø B (TB)	21	Boys	16
		Girls	5

The students that are selected into the Talent Centre program are done so from the application information consisting of; an application form, an interest form, recommendations form both teachers and parents in addition to an essay written by the students themselves. From this information the students are characterised into the six types of talented students according to Betts and Neihart. The students are selected according types mentioned in section 2.2.1. Even if the Talent Centre mainly focus on type 3 and 4 students, is it noted that there will be a percentage of type 1 mixed into the subject groups. This is due to that this type of student is one of the easiest to identify and it is the type teachers often recommend to the Talent Center, even if it is not the group they focus on [4]. This was particularly noticeable with the subjects in Bodø, where most of the students gave the indication of being type 1.

3.2 The teaching plan and implementation

To further explore the thesis question was a tailored lesson program developed. The theme for the Talent Center was Communication and Programming. Thereby, was the teaching program tailored around the chosen theme wireless communication.

The assembly was planed around two of the Norwegian curriculum objectives in science for 8-10 grade [36]:

- *«explore, understand and make technological systems that have a transmitter and receiver»*
- *«use programming to explore natural-science phenomena»*

Since this teaching plan is tailored for students with high learning potential in mind, covered some of the material the curriculum objective for Year 1 of Norwegian High School (VG1) [37]

- *«explain the main principles of wireless communication and give examples of applications of this technology»*

The goal for the teaching plan then became to give the students an understanding:

1. of what communication is,
2. some of the ways we communicate today,
3. some of the principles and technology behind wireless communication.

The lesson program was created with the STEAM approach in mind and the theme continues thread throughout the two-day assembly, included into the get-to-know activities in the beginning of the assembly as the assembly was the first of the year. The main element happened on day 2 of the assembly, where a whole day teaching program "Robot ball for 8-10 grade" crated by *Skaperskolen* [38] was used (see appendix A.2.8). The mission was in teams (of four students) to program a radio controlled Bit:Bot to play in a corner football tournament. Day 1 was used to give the students the knowledge of how the radio-controller worked, though lectures and explanations, with discussions, demonstrations and hands-on activities throughout the lesson. The discussions was around what communication is and the different forms of communication (see appendix A.2.1), what would they do if it was their responsibility to create a new "Golden Record" (see appendix A.2.2), what different type of communications are being used today and how we use wireless communication to locate where we are with a GPS satellite network. The demonstration used was in form of vacuum-clock, see appendix A.2.4 to show how sound and light waves are different and the reason we use electromagnetic waves for communication in space. The hands-on activities included, creating a paper phone (see appendix A.2.3), triangulate their position (see appendix A.2.5) and program a simple/not so simple wireless communicator with use of micro:bits A.2.6.

The assembly was held at different locations in Norway. The assembly for subject groups TA and TB, where held at the Science Center in Tromsø with access to a planetarium, for the group A at the Science Center branch department in Alta and for the group B in Bodø the assembly was held in normal school classroom. The full detailed teaching plan for subject groups can be located in the appendix A.1 in order of implementation, group TA and TB inn A.1.1, group A in A.1.3 and group B in A.1.2. Since Alta and Bodø did not have access's to a planetarium thereby the program was slightly changed for these two groups. In Tromsø for groups TA and TB the planetarium was used to show how our communication network in space looks like and how astronomers collect data from satellites and distribute it around the world. In addition was the physical demonstration of the vacuum-clock used. In Alta and Bodø was the planetarium swapped with an activity on communication with help of lasers created by Science Centre [39]. Here the students was given the task of build a communicator form scratch through set of instructions that could transmit sound from one point in the room to another through a laser beam. This lead to the discussion on how lasers are being used by satellites to transmit information through space and the similarities between this type of communication and the way our phones communicate. The physical demonstration of the vacuum-clock was also swapped out with a video demonstration for group A and B, due to the lack of access in resource.

On day 2 starter exercise "Which does not belong?" (see appendix A.2.7), which does not have a specific correct answer was used to shows that there are several ways to solve a problem. Thereafter the full task was presented to the students and the full program for the rest of the day. Firstly, the students was asked in groups of two students to write a program for micro:bit that work as a radio-control to make the Bit:Bot minimally drive forward, stop and turn. Then the students presented their solution for the whole class, to help each other to see the different ways the problem could be solved. Thereafter was the students given extra material such as paper, popsicle sticks, etc. in addition to servos to build up their bit:bots to have an extra advantage in the tournament. In the tournament the class was divided into teams of two bit:bots with four students as far as it was possible. The rules of the tournament was was decided by the students themselves as a class, before they started building up their Bit:Bot for the tournament so everybody was in agreement. The day ended with the tournament itself, where every team had a match against every other team to see which team was the overall winner.

The assemblies was completed in order of group TA, TB, B and A. In addition to the change between Tromsø and Alta/Bodø mentioned above there was also small changes in the timetable between the different assemblies based on the experience form previous assemblies. Especially, in the time setup of day two, after the experience from group TA, where the time the students had on designing and building up their bit:bot increased for the assemblies that came after.

3.3 Data Collection and analysis

To find the answer to the thesis question the data was collected from multiple sources. The main source of quantitative data was collected with a multiple-choice pre- and post-test. To get a clarification of the results and the possible reasons behind it some qualitative data was collected in form of an evaluation survey done by the Talent Center and observational notes by the author throughout the whole process. Even if the main bulk is quantified data will it be acknowledged that the result will not be clear cut and what we see will depend on the observer, in this case the authors point of view [[40], p. 16-17]. Thereby, the research in this study will have a post-positivists approach.

3.3.1 Pre- and Post-test

The multiple-choice pre- and post-test was used to collect the data needed to calculate the knowledge gain in accordance to equation 1. The exact same ten multiple-choice questions was used in both the pre- and post-test to give a "very" clear picture of how much knowledge the student has gained during the assembly. By choosing the same multiple-choice questions error in marking and and misinterpretation in the student answer has been eliminated, where all the answer follow a clear picture, either correct or incorrect [40], which elevate the reliability of the test result. the number of question ten in total was chosen to not make the test to long and thereby loose the interest of the students, which in turn could lead to an unreliable result [[40] p. 280-281]. The pre-test was given at the beginning of the assembly on day one after the general get-to-know activities and general information about the Talent Center, but before the teaching itself began. The students was never given the answers to the pre-test and was not told about the post-test that was given at the end of the assembly before the post-test itself was given. This was done to achieve a higher accuracy in the answers so that the test, tested the students understanding and knowledge and not just simple facts and thereby give a a more realistic knowledge gain value g.

The questions and answer options themselves for the pre- and post-test are given in table 2. In addition to the given answer option seen in table 2, there was a last answer option which was the same for each of the questions, "I don't know", not included in table 2 marked as an incorrect answer in the analysis. The option was added and emphasised to the students to minimise the risk of the students just guessing at the answer the boys as well as the girls [[40], p. 281], which in turn would have decreased reliability of the pre- and post test. The students were told that this was the answer they should give if they were very unsure or didn't know the answer. In other words:

> *"If you do not know the answer, I would rather you answer that on every question this is true than guess at the answer"*
>
> [The exact words said to the students, translated from Norwegian]

The questions was chosen from the goal form the teacher plan 3.3.1, where several of the questions ask about the same phenomena (i.e. question 3, 6 and 7) to see whether the student actually grasped an understanding phenomena itself instead of just random facts. Thereby, showing a higher level of understanding by the students. In addition was the test given to three students in a pretrial to clear up any misunderstanding in the questions themselves. From this was a few small changes in the language used in the questions done, to minimize these misunderstandings.

The data from the pre- and post-test was only used if the following condition was met: there was a result from both the pre and post-test with the same subject number. For the analysis of the knowledge gain g a program i Matlab was created to help with the calculations of the knowledge gain according to equation 1 and visual representation of the result of the quantitative data from the pre- and post-test. The results was then visually displayed as graphs for each of the subject groups as well as collective display of all the groups together, with the data points are colour coded according to gender as well as the the average knowledge gain for the group including the different genders. In addition was the mean value of the knowledge gain g of a random subject group calculated by hand to check the accuracy of the program. To get a clearer indication of frequency of the knowledge gain value g from the calculation of the pre- and post-test, was a histogram is shown according to the level of knowledge gain low-g ($g < 0$), medium-g ($0.3 \leq g < 0.7$) and high-g ($g > 0.7$). In addition to a histograms with gender separation for the knowledge gain levels. To analyse the students knowledge gain around the different goals themselves was the average knowledge gain for each of the questions calculated and the correct answer responds rate visually displayed in ha histogram. All the different calculation and figures will be used collectively to get an indication of how mush the students learn during the teaching setup.

3.3.2 Evaluation survey done by the Talent Center

The Talent Center itself has an electronic evaluation survey for the students to answer after each assembly tested and used over several years and thereby have an high validity and reliability. This was given only to one of the four subject groups, Bodø. Some of the question given in the survey, seen in figure 6, are of interest in relation to the thesis question. The full survey can be found in the appendix B.1 The questions was either answered on a rating scale of 1 to 5, where the students indicate their negative-to-positive strength of agreement or strength of feeling regarding the question, (1 = strongly disagree, 2 = partly disagree, 3 = neither agree or disagree, 4 = partly agree and 5 = strongly agree), multiple choice ("Yes", "No", "I don't know") or in form of a open short written answer. The survey is given electronically and is totally anonymous to let the students feel free to answer honestly without judgement. The survey is used by the Talent Center itself to adjust their own future programs dependent on the Talent Center group themselves. The questions of interest that was chosen to give an indication of the how much the students learned form their own perspective.

The mean values are calculated according to the students agreement to acquire a indication of the assembly from the students perspective as a whole class. The analysis method used on the written answers are the result sorted out into general categories out from key words used. Form the first read though was it clear that there was two main categories "Nothing" and "All the talking" when it came to the question about what the students did not like about the teaching setup. For the questions about what the students liked on the other hand was the the categories divided into the different activities used in the teaching setup.

3.3.3 Observation notes

To try and get clarity of the resulting knowledge gain calculated form the pre- and post-test in correlation with the teaching program was there written observational notes in form of after action

Questions given on the Talent Center's evaluation survey:
Question answered according to agreement

- I have learned a lot in talent assembly
- I think what we have done at talent assembly is relevant to my learning of subjects at school
- I sometimes thought the academic level was too HIGH in this talent assembly
- I sometimes thought the academic level was too LOW on this talent assembly
- I have become more motivated in mathematics and science because I have participated in talent assembly

Question answered with a short written statement

- I enjoyed these activities at the Talent assembly
- I did not like these activities very much

[Translated from Norwegian]

Figure 6: Some of the questions given on the Talent Center evaluation survey

Table 2: Pre and Posttest Questions, where the correct answer is marked in green

	Question	Answer Options			
1	What, generally is communication?	Shearing of ideas and information	Talking to another person	Sending a picture on Snapchat	To to something in community
2	What do all communication systems have in common?	Receiver, information carrier, protocol and senders	A receiver which sends information through electromagnetic waves	A control that sends a signal to the TV	A receiver and a sender
3	An exposition can be heard in space.	True	False		
4	Radio waves belong to the wave type	Electromagnetic radiation	Pressure waves	Mechanical waves	Light waves
5	Light needs a medium to move	True	False		
6	What is the difference in the speed of sound and light in air and water?	Both sound and light move faster in the air than in water.	Sound moves faster in water than air, but light moves just as fast in both mediums.	Sound moves more slowly in water than in air, but light moves just as fast in both mediums.	Sound moves more slowly in the air than in water, but light moves faster in the air than in water.
7	How do GPS satellites measure distance?	Using sound.	You only need the speed of light.	Using time.	Using measuring tape.
8	How many GPS satellites do you need at least to cover today's GPS network on earth?	24	32	360	3
9	Triangulation is a method of finding an unknown point by measuring the distance to two or more known points.	True	False		
10	The Doppler effect can help to show that	the universe is expanding	there is a parallel universe	wireless communication works	God exists

reports as a short summery of what happened, in the aftermath each assembly day to further strengthen the study findings. In addition was the author present at the parent-teacher conference held for subject group A in Alta after day 1 of the assembly, where noticeable observations have been added to the after action log for this group. All the observation was of the second degree [41] or a *participant-as-observer* [40], where the revealed observer (in this case the author) was actively involved in every situation that was observed as an educator. The after action log was written as soon as possible in the aftermath of the execution of each assembly day the to keep the observers interpretation of what happened effect the data as minimally as possible.

The after action log were analysed used using keyword such as the names of the activities to help find a connection between the knowledge gain and the teaching program itself based on the students interest through observation of the students engagement and level of interests which created differences in the execution of the teaching program itself and some of the directions the discussion took.

3.4 Ethics

To preserve the ethics in this thesis all the data was collected anonymously and the only personal information collected was the students gender. The students participated voluntarily in the tests and surveys and could choose at any time not to participate. To calculate the knowledge gain needed the collected result form the pre- and posttest be connect to the same student. To maintain the students anonymity was the students each given a random number, which the student's used as identification in the tests instead of their names. This number was discarded by the student's as soon as the post-test was over, so the number could be connected to a specific student. In the after action log was names never noted. Instead notation such as as student, group and class used. Thereby, can not any of the data collected be connected to one specific student.

4 Results

To answer the thesis question is the results and analysis of the data presented separately according to the data collection method, pre- and post-test, the evaluation survey and the after action logs.

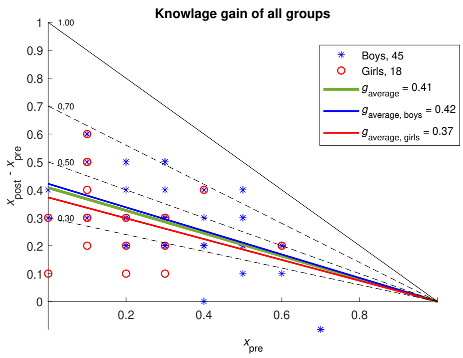
4.1 Results of the pre- and post-test

The pre- and post-tests data that fulfilled the condition of having both an answered pre- and post-test for the same student number numbered at $N_{tot} = 63$ ($N_B = 45$ are boys and $N_G = 18$ are girls), which gives an usable response rate of 84%. The response distribution according to the separate subject group is listed i table 3.

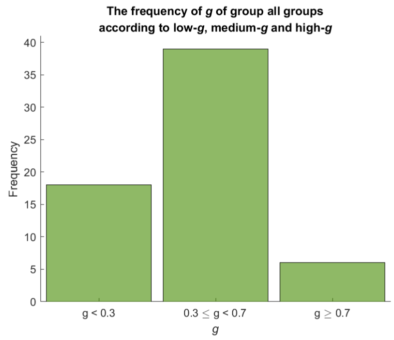
Table 3: The data pool composition, subject group and gender distribution

Subject Group	**Total number of students in the data pool group**	**Gender distribution**	
Alta	10	Boys	10
		Girls	-
Bodø	15	Boys	11
		Girls	4
Tromsø A	18	Boys	9
		Girls	9
Tromsø B	20	Boys	15
		Girls	5

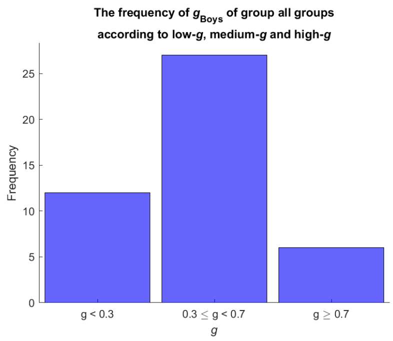
The analysis of the calculation of the knowledge gain from the pre- and post-test are represented in figure 7-11, where the achieved knowledge gain is showed in a graph according to the pre-test represented in (a) in each of the figures 7-11. The frequency of the knowledge gain for the whole subject group according to the knowledge gain level range is represented in (b) in each of the figures 7-11. The frequency of the knowledge gain for the boys subject group according to the



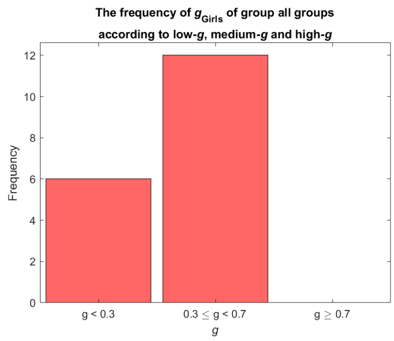
(a) A visual graph of the knowledge gain for all groups



(b) Histogram of the knowledge gain frequency for all groups, according to low-g, medium-g and high-g

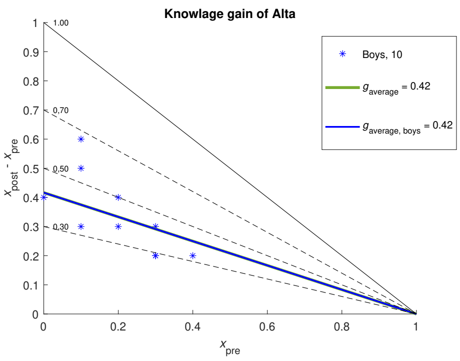


(c) Histogram of the knowledge gain frequency for the **boys** all groups, according to low-g, medium-g and high-g

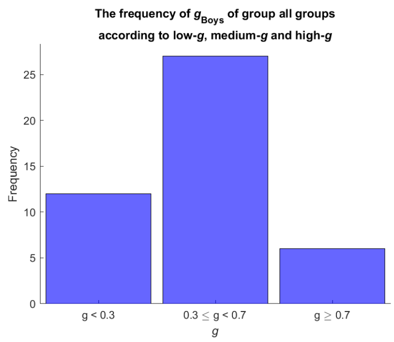


(d) Histogram of the knowledge gain frequency for the **girls** all groups, according to low-g, medium-g and high-g

Figure 7: The plotted result of the calculated knowledge gain for all groups. (a) represents the visual graph of the knowledge gain, (b) the histogram of the knowledge gain frequency and (c) the histogram of the knowledge gain frequency with gender separation.

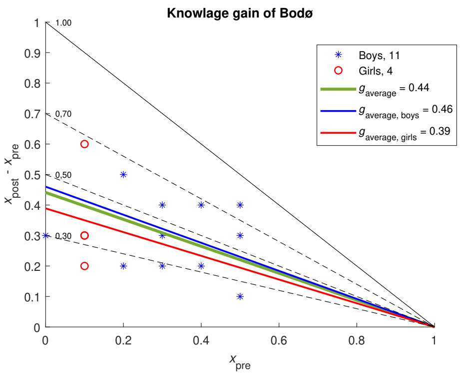


(a) A visual graph of the knowledge gain for all groups

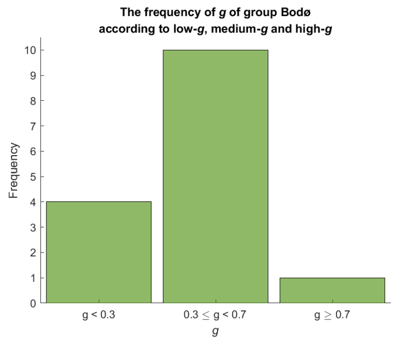


(b) Histogram of the knowledge gain frequency for the **boys** group A, Alta, according to low-g, medium-g and high-g

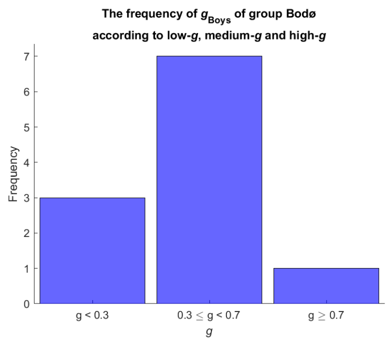
Figure 8: The plotted result of the calculated knowledge gain for group A, Alta. (a) represents the visual graph of the knowledge gain, (b) the histogram of the knowledge gain frequency and (c) the histogram of the knowledge gain frequency with gender separation.



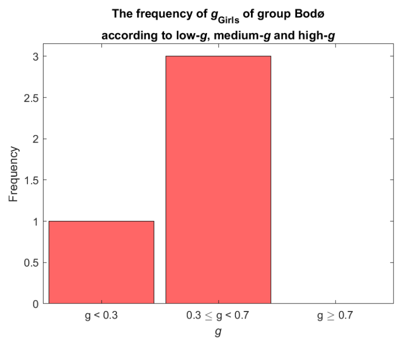
(a) A visual graph of the knowledge gain for all groups



(b) Histogram of the knowledge gain frequency for all groups, according to low-g, medium-g and high-g

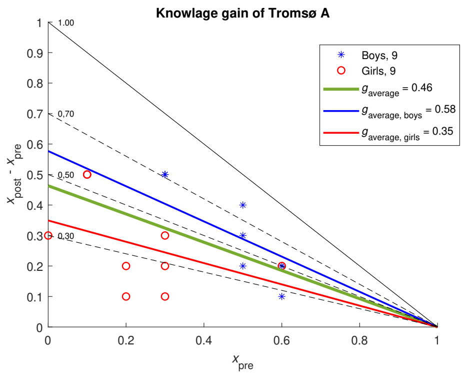


(c) Histogram of the knowledge gain frequency for the **boys** all groups, according to low-g, medium-g and high-g

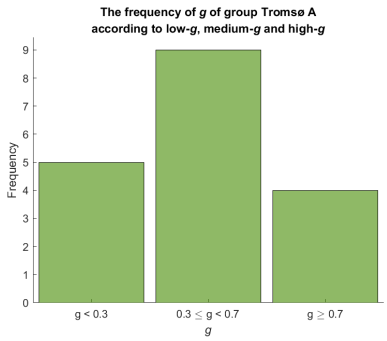


(d) Histogram of the knowledge gain frequency for the **girls** all groups, according to low-g, medium-g and high-g

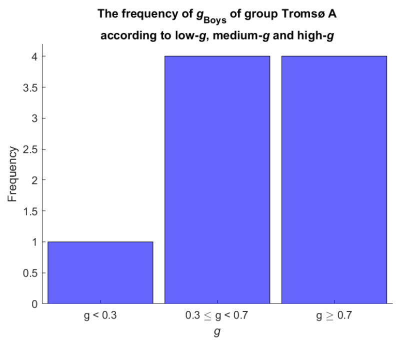
Figure 9: The plotted result of the calculated knowledge gain for group B, Bodø. (a) represents the visual graph of the knowledge gain, (b) the histogram of the knowledge gain frequency and (c) the histogram of the knowledge gain frequency with gender separation.



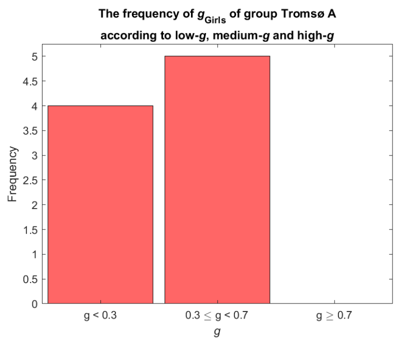
(a) A visual graph of the knowledge gain for group TA, Tromsø A



(b) Histogram of the knowledge gain frequency for all groups, according to low-g, medium-g and high-g

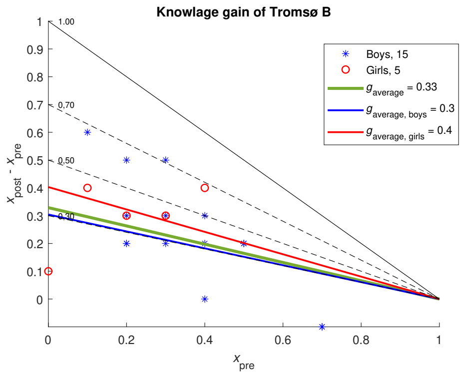


(c) Histogram of the knowledge gain frequency for the **boys** all groups, according to low-g, medium-g and high-g

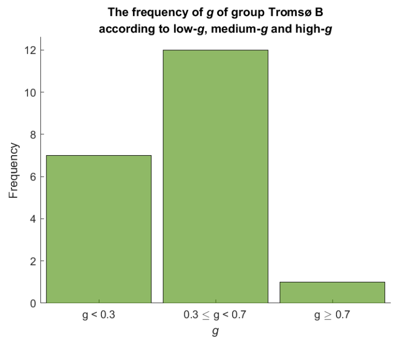


(d) Histogram of the knowledge gain frequency for the **girls** all groups, according to low-g, medium-g and high-g

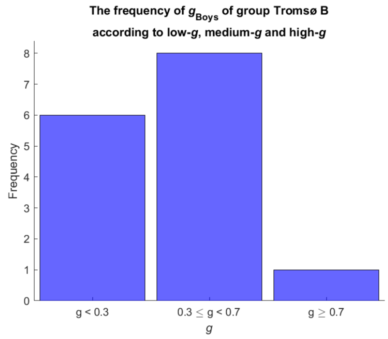
Figure 10: The plotted result of the calculated knowledge gain for group TA, Tromsø A. (a) represents the visual graph of the knowledge gain, (b) the histogram of the knowledge gain frequency and (c) the histogram of the knowledge gain frequency with gender separation.



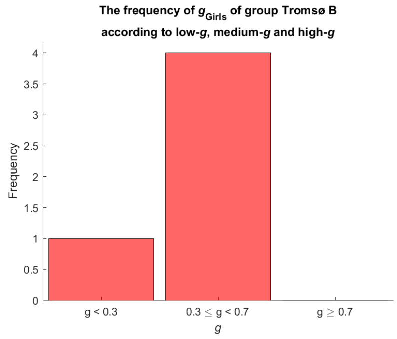
(a) A visual graph of the knowledge gain for group TA, Tromsø A



(b) Histogram of the knowledge gain frequency for all groups, according to low-g, medium-g and high-g



(c) Histogram of the knowledge gain frequency for the **boys** all groups, according to low-g, medium-g and high-g



(d) Histogram of the knowledge gain frequency for the **girls** all groups, according to low-g, medium-g and high-g

Figure 11: The plotted result of the calculated knowledge gain for group TB, Tromsø B. (a) represents the visual graph of the knowledge gain, (b) the histogram of the knowledge gain frequency and (c) the histogram of the knowledge gain frequency with gender separation.

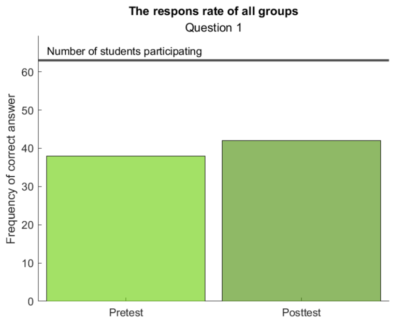
knowledge gain level range is represented in (c) and the frequency of the knowledge gain for the girls subject group according to the knowledge gain level range is represented in (d) in each of the figures 7-11. A summary of the calculated average knowledge gains value for each subject group is listed in table 4.

Table 4: The result of the average knowledge gain, including gender separation

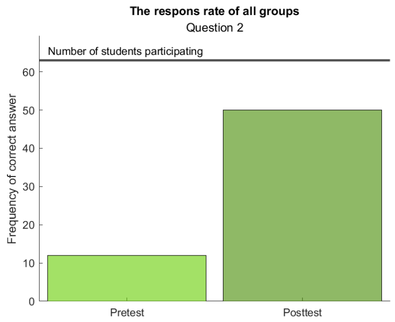
Subject group	**Mean Knowledge Gian (g)**	**Mean Knowledge Gian for the Girls (g_{G})**	**Mean Knowledge Gian for the Boys (g_{B})**
Alta (A)	0.42	-	0.42
Bodø (B)	0.44	0.39	0.46
Tromsø A (TA)	0.46	0.35	0.58
Tromsø B (TB)	0.33	0.40	0.30
All	**0.41**	**0.37**	**0.42**

The table 4 and figure 7 shows that the average knowledge gained by the students from the tailored teaching setup was valued at $g_{\mathrm{ave}} = 0.41$, which falls with the middle-g of the knowledge gain level rages. The boys averaged at a knowledge gain value $g_{\mathrm{ave,B}} = 0.42$ and the girls averaged at a knowledge gain value $g_{\mathrm{ave,G}} = 0.37$. Thereby, had the boys an higher knowledge gain of 0.05 form the tailored teaching setup than the girls. Interestingly, the knowledge gain value was 0.05 higher than the average knowledge gain value the first time the teaching setup was executed with subject group TA $g_{\mathrm{TA}} = 0.46$, which was the highest knowledge gain out of all the groups.

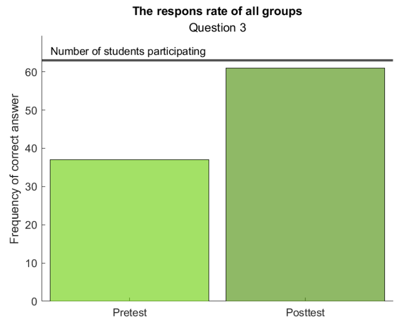
The analysis into the questions themselves is visualised as the correct answer rate according to the pre- and post-test given in figure 12-16, where each figure represents a separate subject group. A summery of the knowledge gain value calculated according to equation 1 for the the knowledge gain from each of the questions is listed in table 5. The table and figures gives a clear indication that there was some questions had higher knowledge gain than others, where one question (question 10) even shows that the teaching setup had a negative effect. Generally, shows table 5 that the knowledge gain mostly falls within the middle-g level range, where question 4, 5 and 7 at the lower end and question 8, 9 at the higher end. Some question reached the knowledge gain value the high-g level range (question 2 and 3), in addition to some question at the low-g (question 1, 6 and 10).



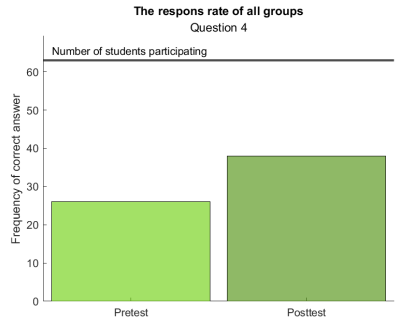
(a) Question 1



(b) Question 2



(c) Question 3



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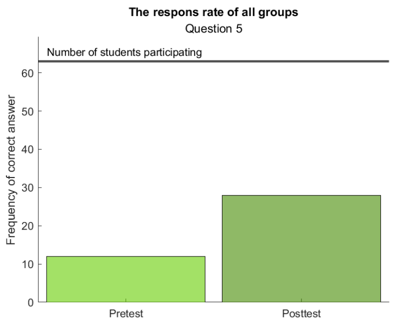
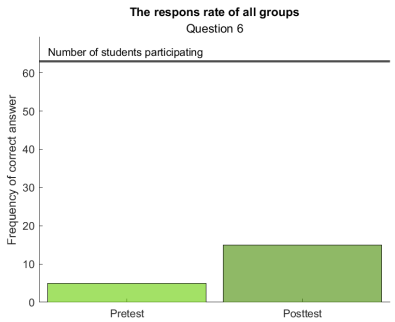
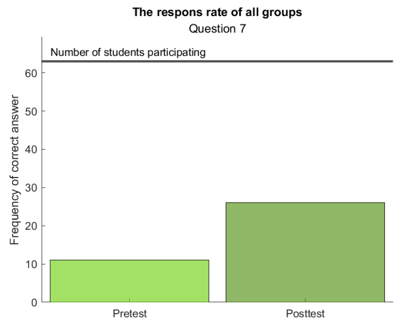


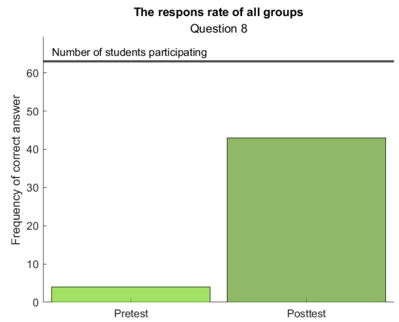
(e) Question 5



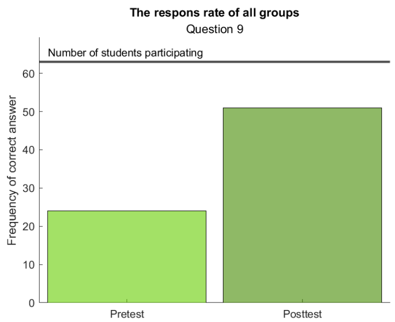
(f) Question 6



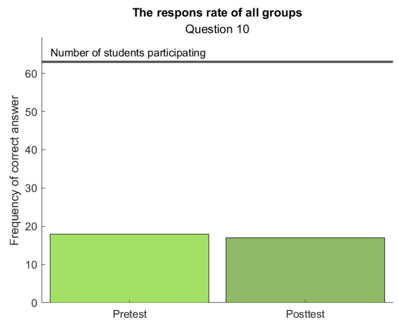
(g) Question 7



(h) Question 8

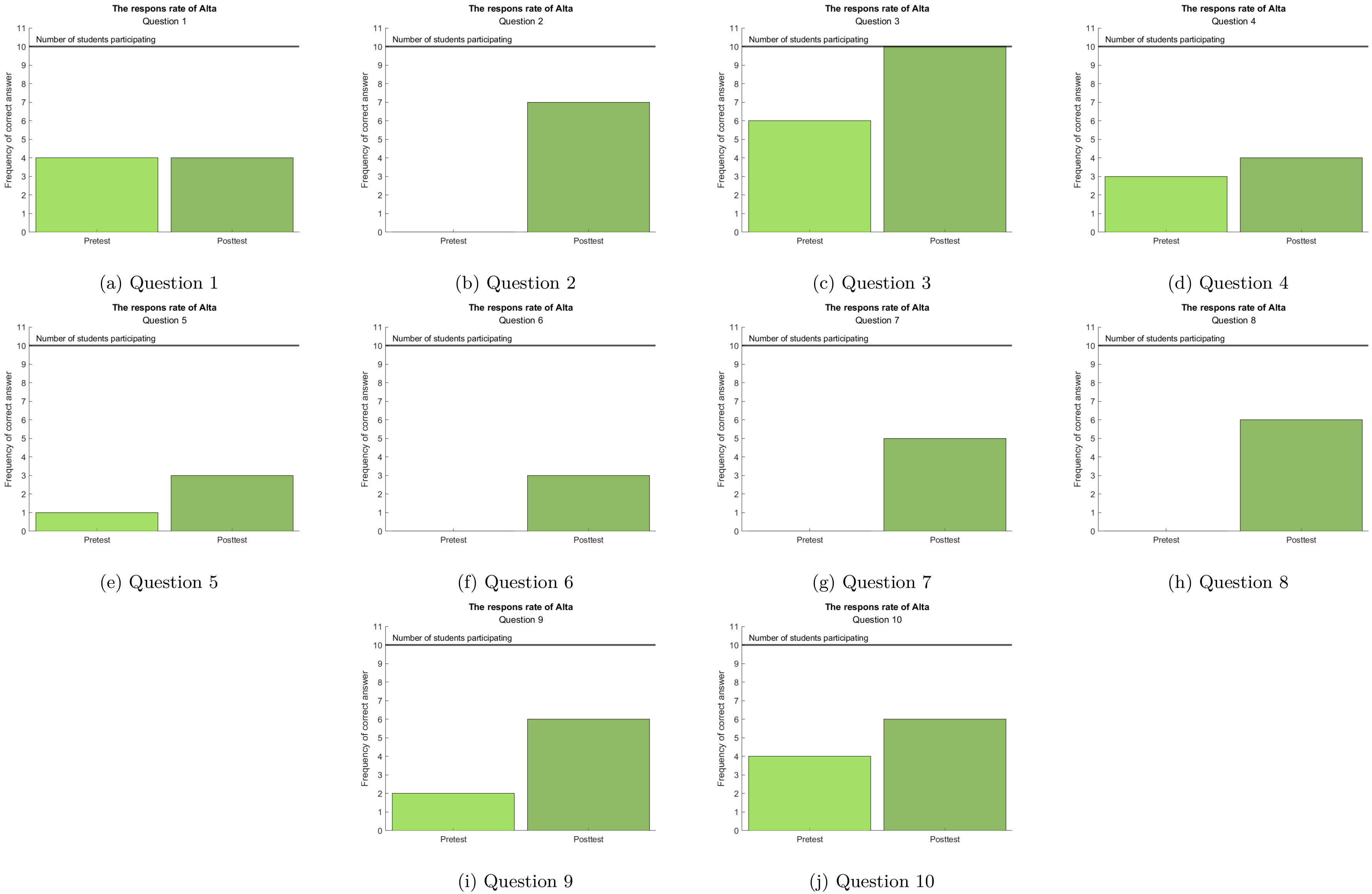


(i) Question 9



(j) Question 10

Figure 12: A visual representation in form of a histogram of the response rate in according to the pre and post-test of all groups.

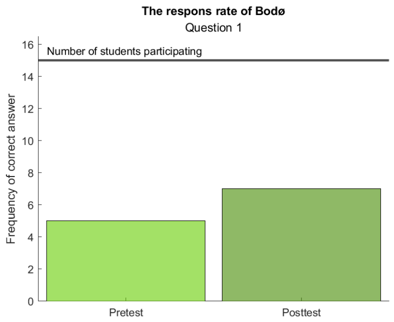


(a) Question 1 (b) Question 2 (c) Question 3 (d) Question 4

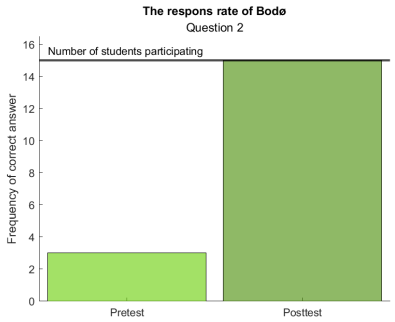
(e) Question 5 (f) Question 6 (g) Question 7 (h) Question 8

(i) Question 9 (j) Question 10

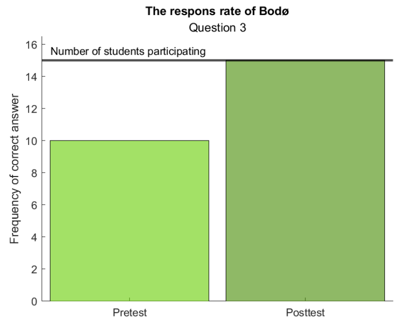
Figure 13: A visual representation in form of a histogram of the response rate in according to the pre and post-test of group A, Alta.



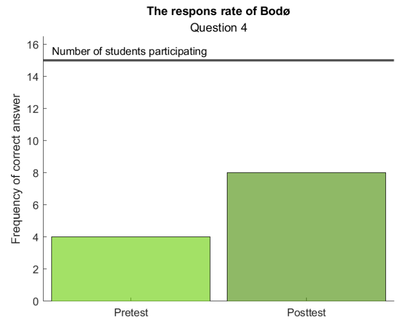
(a) Question 1



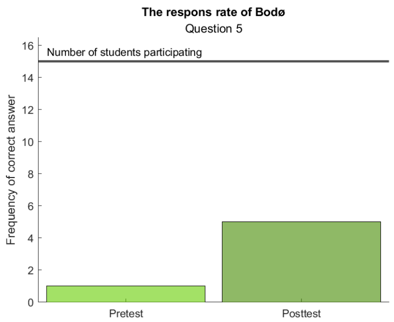
(b) Question 2



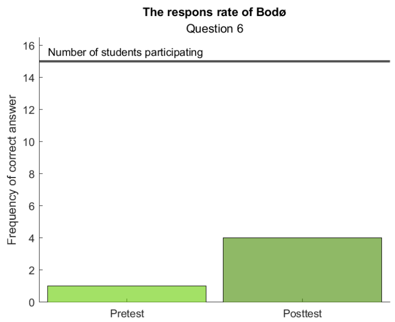
(c) Question 3



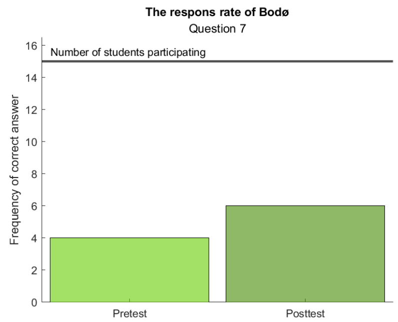
(d) Question 4



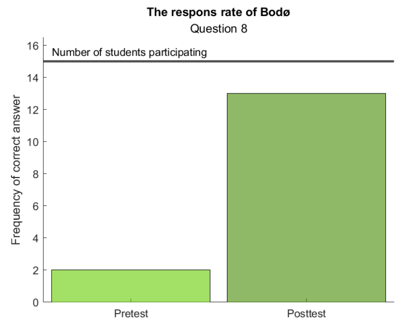
(e) Question 5



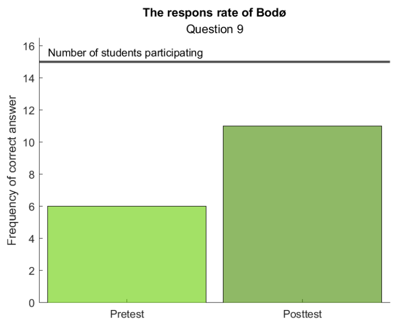
(f) Question 6



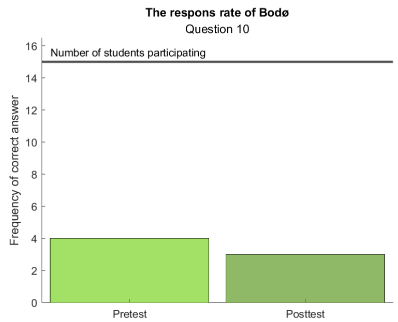
(g) Question 7



(h) Question 8

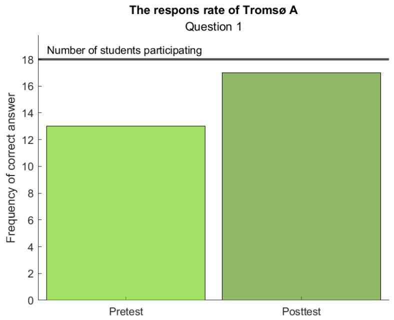


(i) Question 9

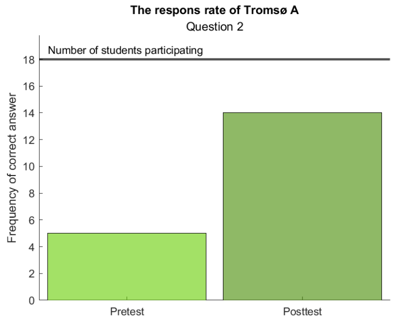


(j) Question 10

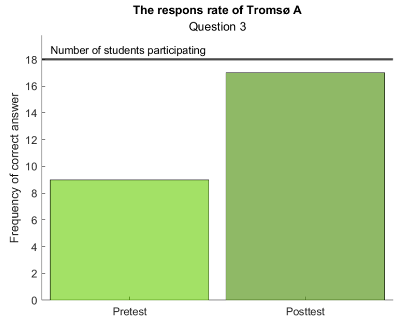
Figure 14: A visual representation in form of a histogram of the response rate in according to the pre and post-test of group B, Bodø.



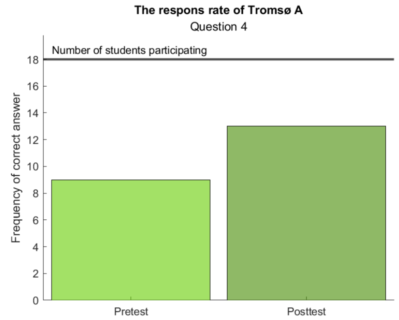
(a) Question 1



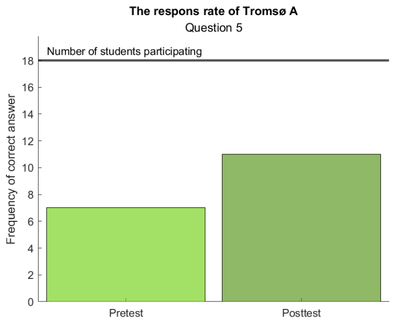
(b) Question 2



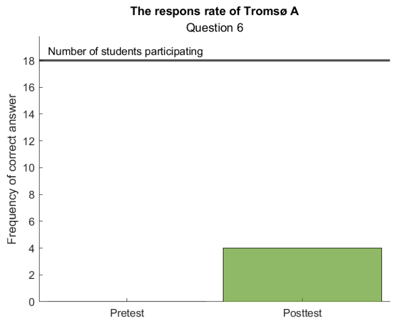
(c) Question 3



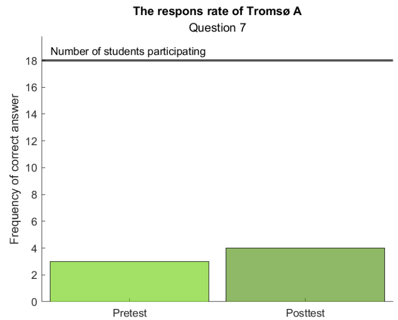
(d) Question 4



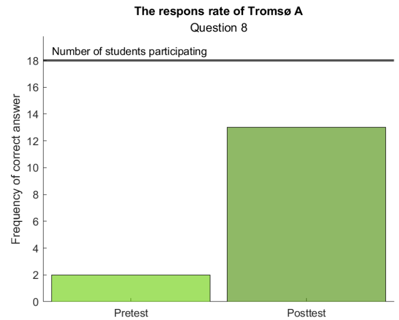
(e) Question 5



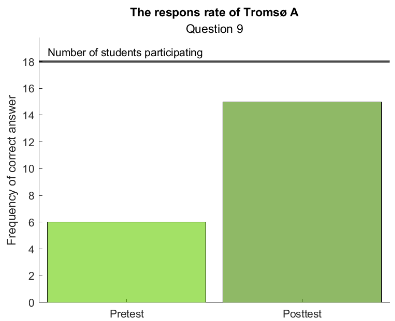
(f) Question 6



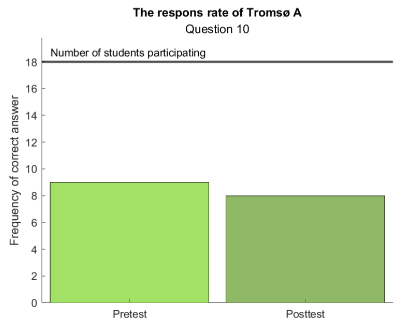
(g) Question 7



(h) Question 8

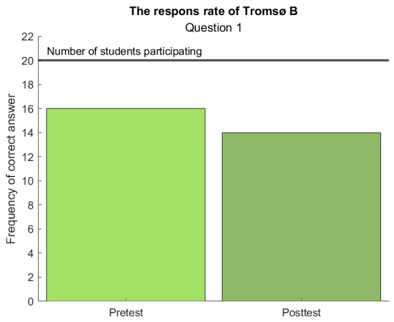


(i) Question 9

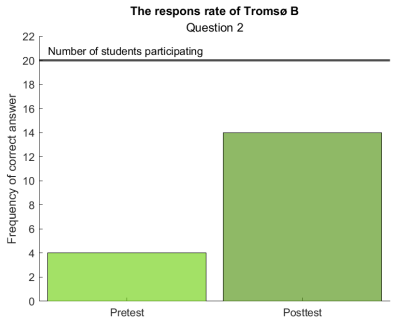


(j) Question 10

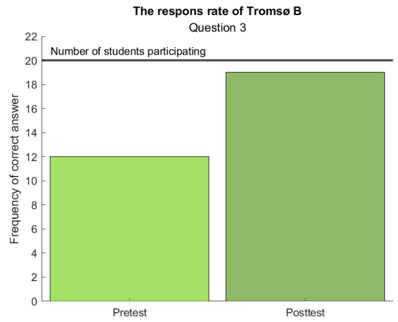
Figure 15: A visual representation in form of a histogram of the response rate in according to the pre and post-test of group TA, Tromsø A.



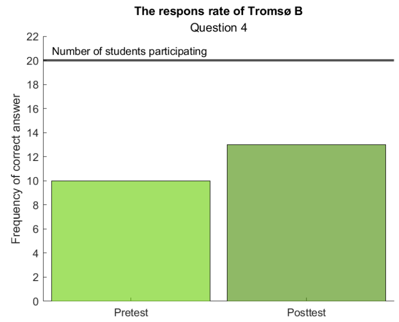
(a) Question 1



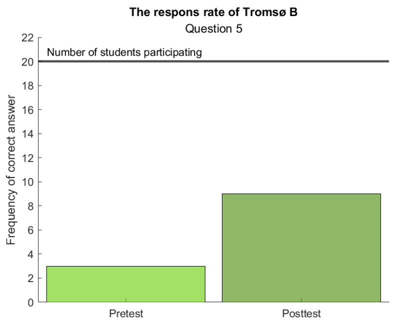
(b) Question 2



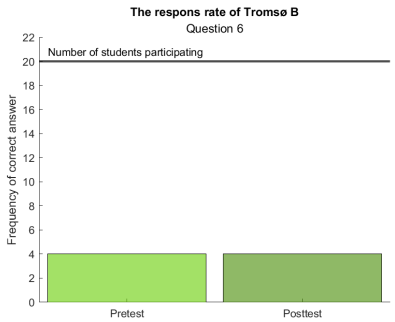
(c) Question 3



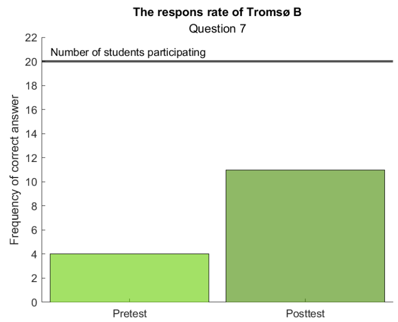
(d) Question 4



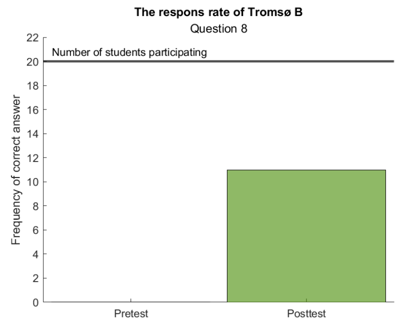
(e) Question 5



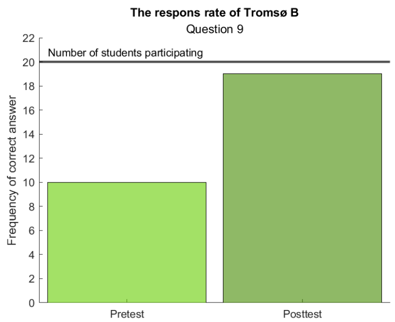
(f) Question 6



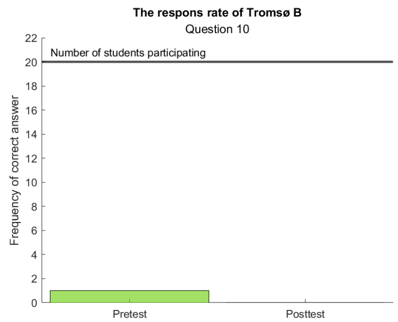
(g) Question 7



(h) Question 8



(i) Question 9



(j) Question 10

Figure 16: A visual representation in form of a histogram of the response rate in according to the pre and post-test of group TB, Tromsø B.

Table 5: The knowledgain g of each question based on subject group, where $g < 0$ is marked in red, $0 \leq g < 0.5$ marked in blue and $g \geq 0.5$ marked in green.

Question	Group				
	All	**A**	**B**	**TA**	**TB**
1	0.16	0	0.20	0.80	-0.50
2	0.75	0.70	1.00	0.69	0.63
3	0.92	1.00	1.00	0.89	0.86
4	0.32	0.14	0.36	0.44	0.30
5	0.31	0.22	0.29	0.36	0.35
6	0.17	0.30	0.21	0.22	0
7	0.29	0.50	0.18	0.07	0.44
8	0.66	0.60	0.85	0.69	0.55
9	0.69	0.50	0.56	0.75	0.90
10	-0.02	0.33	-0.09	-0.11	-0.05

4.2 Results form the evaluation survey in Bodø

The response rate from the Talent Centres survey given to group B in Bodø was at 94% responds rate ($N_{survey} = 16$). The results form the analysis of the questions of interests from the survey is listed in table 6, where the mean value of the students agreement to the statements was calculated to get a indication of the class opinion as a whole. The result indicate that according to the students themselves; have they gained a lot of new knowledge, the teaching setup was relevant and the teaching setup academic level was mostly neither to high or to low. In addition shows the result that even thought these are students with a high interest in the science subjects already, became they slightly more motivated after the assembly. From the analysis of the students written answers

Table 6: The result form the evaluation survey given by the Talent Center in Bodø

Question	**The mean result value**	**Mean opinion to the questions**
I have learned a lot in talent assembly	4.0	partly agree
I think what we have done at talent assembly is relevant to my learning of subjects at school	3.9	partly agree
I sometimes thought the academic level was too HIGH in this talent assembly	2.1	partly disagree
I sometimes thought the academic level was too LOW on this talent assembly	2.0	partly disagree
I have become more motivated in mathematics and science because I have participated in talent assembly	3.5	neutral/partly disagree

to the questions of what they liked about the assembly, which every student who answered the survey gave an answer to (100% response rate), was it clear they the students liked best the hand-on activities and especially the main mission used on the second day. Other honorable mentions was "the paper cup phones" and "laser communicator" On the question of what the students liked the least answered just half of the students the question (response rate of 56%) where the answers belonged to either of the two following categories: "Nothing" (31%), "All the talking" (25%). Form these answers the only thing students did not like was the more traditional forms of teaching.

4.3 Differences in the teaching execution

Two teaching executions is never executed the same even if it follow the same teaching setup and plan. Apart form the difference due to resources, see teaching program i appendix A.1 and the changes in teaching program based on the experience from the educators, had the students own interests an effect on the direction the discussions took. The data collected in from of the after action logs are presented in the appendix B.2. The action loges shows especially the effect the the students interest in during the discussions about "the Golden Record". Group TA, was more interested in the psychological aspect on how a message can be preserved through our different senses, for example how a smile with teeth in the human world is a reassuring gesture, but in the animal kingdom it is often a threatening gesture. Group TB interest went more in a biological direction, where the discussion circled back to the different ways the senses are used to communicated. Group B on the other hand had an interest in the technological aspect, where the student discussion focus around the the different formats of communication. The group in Alta, group A was not very active in the discussion thereby, was the discussion more in form of a lecture from the educators point of view.

There was also several other differences in the execution of the teaching program between the groups. Group TA was the only group that did not do the activity "Triangulation of Satellites", due to some of the other exercises ended up taking to much time. Thereby was it decided to drop this activity and instead cover this deeper during the lecture in the planetarium, where the student were shown the GPS-network. Group TB on the other hand was the only one of the two groups that covered the program for Tromsø in its entirety. Group B, became the students so engaged into the activity "paper cup phone". That they took the activity a step further in a direction, which was not expected where the students build up their own massive network as a whole class (more detail see appendix **??**. In addition was group B the only group which did not go though the inductive lecture on micro:bit and micro:bit programming due to the fact that everybody had prior knowledge on how to use them. Group A also took the activity "paper cup phone" in an unexpected direction where the whole class ended up testing how long they could make the sting and still be able to hear a sound.

During the day 2 of the assembly was the teaching plan followed as planed for groups A, B and TB based on the experience form group TA, which was the first assembly of them all. Form the experience with group A was the time for the building and design process extended for group A, B and TB. In addition experience group TA some problems with the wireless signals between the micro:bit and the controller at no fault of the students design and program. This opened opp for a discussion into what could hinder the electromagnetic waves and how they traveled in different medium to try and find the reason for the problem.

5 Discussion

The analyses of the quantitative data showed the main findings:

- The knowledge gain for the tailored teaching setup on wireless communication was within the middle-g level of the knowledge gain range with a average value of $g = 0.41$.
- The boys seemed to have a higher knowledge gain than the girls from the teaching setup on wireless communication
- According to the students themselves, found they the assembly both educational and relevant as well as the academic level mostly was neither to high or low.

5.1 Discussion of the knowledge gained in light of theory

The teaching program was created with students with high learning potential with an STEAM approach in mind. The (T), (E) and (A) played the main role in the creation of the bit:bot used in the robot ball tournament and (S) and (M) supplemented the knowledge to understand some of the principle of how the radio controller used to control the robot worked. The Talent Centre main focus is on the talented students of type 3 and 4. Thereby was an interactive teaching program created with a lot of student centered activate. Earlier research indicate that a more student active approach have an positive effect on students knowledge growth. A certain level of the use of more traditional teaching methods such as short lectures and explanations was not was not possible to be avoided to keep the academic level to a high standard and keep the students that might be in the risk of dropping out due to the lack of academic challenges engaged. From the students own prospective indicated by the survey given to subject group B that they the academic level set in this program was mostly neither to high or to low even though some of the subject matter was a level higher than what is normally thought to students of their age. Further indication on that the tailored teaching was within a suitable sweet spot of the academic level was a comment given by one of the parents at the parent-teacher conference in Alta.

> *"the students was extremely happy with the day as they, unlike after a normal school day, since had been academically challenged and learned something new which apparently hadn't happened in a long time."*

From the students own perspective, the activities the they liked the most was any form of hands on activity and what they liked least was all the talking. Still they generally agreed the students agree that they found the teaching program both educational, relevant slightly motivating and thereby that they had learned a lot.

Looking at the separate elements of the teaching program based on the result of the knowledge gained calculated for each of the separate questions used in, the result shows that there generally is a higher knowledge gain in the high middle-g or high-g for the questions that has a clear connection to the different hands on aciveties, such as question 2, 8 and 9, which has a correlation to activity "paper cup phone" and "Triangulation of Satellite". It can be discussed how effective the activity of since the knowledge gain value from group A for question 8 and 9 is in that same range as group A, B and TB even though group A never did the activity. An exception to the correlation between the knowledge gain based on more student centred aciveties was the question 3, which was demonstrated to the students instead. It interestingly enough had the the highest knowledge gain of all the questions. The demonstration with the vacuum clock was in physical format with groups TA and TB, but in video format for groups A and B. Even though the students of groups TA and TB was experienced by the students themselves though a passive demonstration of the vacuum-clock was it the student that saw the video of the same phenomena that has the highest knowledge gain, but here it could be noted knew also most of the students the answer prior to the assembly. The slightly lower knowledge gain in the groups TA and TB might be some the use of the more passive physical demonstration which was quite loud and hindered the student asking the questions at a few points during the demonstration. This correlates with earlier research sometimes demonstrations does not necessarily help the understand the concept being taught as the educator intended [29]. This point is further supported by the knowledge gain value form question 4-6, which all had a connection to the demonstration with the vacuum-clock, but was not as clearly experiences as the concept in question 3. For the rest of the questions used in the pre- and posttest was the knowledge gain either at the lower end of middle-g range or at the lower-g, which all had a certain degree a more traditional teaching method connected to them. This indicates thereby that a correlation between the the type of teaching method used and that this even has an effect on differed elements with the lesson itself. From this study the average knowledge gain for the tailored teaching program was calculated to a value $g_{\text{ave}} = 0.41$. This result is lower than the effect value 0.5 aimed for, but still within the expected values of the knowledge gain ($0.3 \leq g < 0.7$) from earlier research done by Richard R. Hake [9] for a lesson plan that uses a interactive engagement method, which the tailored teaching setup in this thesis do.

Comparing the knowledge gained for each question from the pre- and post-test for only subject group B, which follows the same pattern as for the all the subject groups, to the students perception of the teaching plan and the teaching method used, shows the result that the students interest and motivation played a role in how much knowledge the students gained. The importance of the students interest and motivation has been shown in several earlier studies [11]. Research into the students interest of different themes such as done by the ROSE study [20], shows that generally boys have a higher interest in themes such as technology than girls. This concur with observation done by the author of the subject group, where the boys had generally had more knowledge and skills in programming than the girls and thereby found the theme more exciting. The group TB, seemed to be the only exception form the authors point of view, which is also reflected in the results of the knowledge gain calculation, where group TB was the only subject group where the knowledge gain was higher in the boys than the girls. In group TB the girls still had a lack of understanding and knowledge around programming in comparison to the boys, but by comparison to the other subject groups showed the girls in group TB a general excitement to learn and work to breach this gap. Several of the boys in group TB on the other had showed a lack of interest in the subject since several of them had according to themselves in a talk with the students in question throughout the lesson. The boys already had a good amount of knowledge on the subject and thereby was found it a bit boring to go though it again according to themselves. This shows a clear indication that the student specified learning outcome which accrue out from the students interest, which is acknowledged as a part which make up a students total learning outcome according to Eisner, can not be predetermined into the goals. This is further confirmed by the discussions occurring in the classroom. The students interests dedicated which direction several of the discussion went, which was essentially noticeable in the in the discussion around "the golden record". This goes to further show that the knowledge gain value g can not give a measurement of the complete knowledge gain within a student which matches Eisner opinion about that a complete students learning outcome can be determined by predetermined goals. On the other hand can not our analysis be completely overlooked and it can be said that it gives an good indication of how much the students has learned and is the best method to give an clear value of the knowledge gain up until now.

5.2 Implications, contributions and further research

It has been done several earlier research of learning outcome and knowledge gain, with different types of teaching methods, but few studies has looked upon the knowledge gain for a single teaching setup or program in the way this thesis did. Teacher uses a lot of time to plan and create good teaching lessons and setups and for them can this thesis bring up an interesting indication of how much the students learn form a just single teaching program and the effect different elements within the teaching program itself has. This might help teachers in how they think of their own use on teaching methods and how they correlate to the knowledge the students gain from their lesson. The thesis focused on student with high learning potential, but further research into the teaching program on wireless communication would it be interesting to if it was just as effective in use on a normal class at school or if the teaching program was truly tailored to students with high learning potential. In addition form the result that the boys seamed to have an higher knowledge gain than the girls would it be interesting to see if this switched based on theme if the chosen theme was more in a driection girls found interesting.

6 Conclusion

In this master thesis has the thesis question: how much knowledge gain can students with high learning potential acquire from a tailored teaching program within the theme wireless communication. The study found the that the average knowledge gained by the students was at a value of $g_{\text{ave}} = 0.41$, which falls within expected values of knowledge gain that uses an interactive engagements thought the teaching setup. The study also found that the students interest had an effect on which direction the discussing took which could not be predicted in the goals set for the pre- and post test and thereby in truth has the student gained more knowledge than the knowledge gain value g can measure by itself.

References

[1] Mirjam Harkestad Olsen and Kjell Skogen. Læringspotensial. Inkluderende skolemiljø. Cappelen Damm akademisk, Oslo, 1. utgave. edition, 2019.

[2] Rolf B. Fasting. Adapted education: the norwegian pathway to inclusive and efficient education. International journal of inclusive education, 17(3):263–276, 2013.

[3] The education act. `https://www.udir.no/om-udir/vare-oppgaver2/`, 2020. LOV-1998-07-17-61.

[4] Hedinn Gunhildrud Elise Fosshaug. Teacher training course: Om elver med stort læringspoteniale., 16. February 2022.

[5] Hedinn Gunhildrud. Personal conversation, April 2022.

[6] Amanda E. V. Gitlesen. Personal notes form practical experience. september, October 2020.

[7] Medietilsynet. Barn og medier 2020. `https://www.medietilsynet.no/globalassets/publikasjoner/barn-og-medier-undersokelser/2020/200211-barn-og-medier-2020-delrapport-1_-februar.pdf`(26.05.22 11:23), 2020.

[8] UiS Kunnskapssenter for utdanning. Bruk av nettbrett i barneskolen, 2022, date = 10. February, howpublished = https://www.uis.no/nb/kunnskapssenter-for-utdanning/ressurser/bruk-av-nettbrett-i-barneskolen(26.05.22 11:43).

[9] Richard R Hake. Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. American journal of Physics, 66(1):64–74, 1998.

[10] Furtak Erin Marie, Seidel Tina, Iverson Heidi, and C. Briggs Derek. Experimental and quasi-experimental studies of inquiry-based science teaching: A meta-analysis. Review of educational research, 82(3):300–329, 2012.

[11] Nani Teig, Ole Kristian Bergem, Trude Nilsen, and Bas Senden. Gir utforskende arbeidsmåter i naturfag bedre læringsutbytte? Universitetsforlaget, 2021.

[12] Katarina Pajchel and Aase Marit T. Sørum Ramton. Hvordan kan et utforskende undervisnings- opplegg i naturfag støtte læring og motivasjon hos elever med stort læringspotensial? NorDiNa, 2021.

[13] Tine Sophie Prøitz. Læringsutbytte. Universitetsforlget, Oslo, 2016.

[14] Utdanningsdirektoratet. Læringsutbytte definisjoner og dimensjoner. https://www.utdanningsforbundet.no/globalassets/var-politikk/publikasjoner/temanotat/2019/temanotat_2019.01.pdf, 2019. Temanotat 1.

[15] Susan Wallace. A dictionary of education. Oxford quick reference. Oxford University Press, Oxford, United Kingdom, second edition edition, 2015.

[16] European Qualifications Framework. Recomendation council, 2017. 22 May.

[17] The Norwegian Directorate for Education and Training (Udir). Våre oppgaver. https://www.udir.no/om-udir/vare-oppgaver2/, 2021. 08. November.

[18] The Norwegian Directorate for Education and Training (Udir). Læringsutbytte - kvalitet i fagopplæringen. https://www.udir.no/kvalitet-og-kompetanse/kvalitet-i-fagopplaringen/Administrasjon/Laringsutbytte/, 02.12 2016.

[19] Tine S. Prøitz and Andreas Nordin. Learning outcomes in scandinavian education through the lens of elliot eisner. Scandinavian Journal of Educational Research, 64(5):645–660, 2020.

[20] Svein Sjøberg. Naturfag som allmenndannelse : en kritisk fagdidaktikk. Gyldendal akademisk, Oslo, 3. utg. edition, 2009.

[21] More to gain: Better learning for students with higher learning potential: Report from the committee appointed by royal decree on 18 september 2015., 2016. Submitted to the Ministry of Education and Research on 15 September 2016.

[22] The Norwegian Directorate for Education and Training (Udir). Elever med stort læringspotensial, 2021.

[23] George T. Betts and Maureen Neihart. Profiles of the gifted and talented. The Gifted child quarterly, 32(2):248–253, 1988.

[24] Mirjam Harkestad Olsen and Peder Haug. Tilpasset opplæring. Inkluderende skolemiljø. Cappelen Damm akademisk, Oslo, 1. utgave. edition, 2020.

[25] Tett på realfag : nasjonal strategi for realfag i barnehagen og grunnopplæringen (2015-2019), 2015.

[26] Hanne Larsen. Avviser at talentsentrene driver med elitedyrking: ett fett hvilke karakter de går ut med. https://www.nrk.no/tromsogfinnmark/avviser-at-talentsentre-bidrar-til-elitedyrking-i-norsk-skole-1.15898210, 28. mars 2022.

[27] Berit Lødding, Ann Cecilie Bergene, Berit Bungum, Jan Sølberg, Jørgen Smedsrud, and Frida Felicia Vennerød-Diesen. Evalueringen av tett på realfag. implementeringen fortsetter. delrapport 3. nasjonal strategi for realfag i barnehagen og grunnopplæringen (20152019). Report, Nordisk institutt for studier av innovasjon, forskning og utdanning NIFU, 2020.

[28] Jan H. van Driel. Section iv: Science teaching. In Norman G Lederman and Sandra K Abell, editors, Handbook of research on science education, volume II, pages 303–319. Routledge, 2014.

[29] David F. Treagust. Chapter 14: General instuctional methodes and strategies. In Sandra K. Abell and Norman G. Lederman, editors, Handbook of research on science education, pages 373–391. Lawrence Erlbaum Associates, Mahwah, N.J., 1st edition. edition, 2007.

[30] Stein Dankert Kolstø, Erik Knain, naturfag Elever som forskere i, and grunnopplæringen og lærerutdanningen Praksisrettet FoU for barnehagen. Elever som forskere i naturfag. Universitetsforl., Oslo, 2011.

[31] Carl Angell. Fysikkdidaktikk. Cappelen Damm akademisk, Oslo, 2. utgave. edition, 2019.

[32] Jan H. van Driel, Tessa E. Vossen, Ineke Henze, and Mare J. de Vries. Delivering stem education though school-industry partnerships: A focus on research and design. In Tasos Barkatsas, Nicky Carr, and Grant Cooper, editors, STEM education: An emerging field of inquiry, Global Education in the 21st Century. Brill Sense, Boston, 2019.

[33] Anders Sanne, Ola Berge, Berit Bungum, Eva Celine Jørgensen, Anders Kluge, Tor Espen Kristensen, Knut Martin Mørken, Anne-Gunn Svorkmo, and Liv Oddrun Voll. Teknologi og programmering for alle - en faggjennomgang med forslag til endringer i grunnopplæringen - august 2016. Report, Utdanningsdirektoratet, 2016.

[34] Becker Kurt and Park Kyungsuk. Effects of integrative approaches among science, technology, engineering, and mathematics (stem) subjects on students' learning: A preliminary meta-analysis. Journal of STEM education, 12(5/6):23, 2011.

[35] Biljana Perlic Liland. Lærerkompetanse i grunnskolen : hovedresulteter 2018/2019, volume 2019/18 of Rapporter (Statistisk sentralbyrå : trykt utgave). Statistisk sentralbyrå, Oslo-Kongsvinger, 2019.

[36] The Norwegian Directorate for Education and Training (Udir). Natural science (NAT0104): Competence aims and assessment: Competence aims after year 10. `https://www.udir.no/lk20/nat01-04/kompetansemaal-og-vurdering/kv78?lang=eng`, 2020. Last acsess 03.04.2022 12:31 [In English].

[37] The Norwegian Directorate for Education and Training (Udir). Natural science (NAT0104): Competence aims and assessment: Competence aims after VG1 programmes for general studies, 2020. Last acsess 03.04.2022 12:31 [In English].

[38] Skaperskolen. Robotball, 8.10. trinn. Last acsess 03.04.2022 12:31.

[39] Hedinn Gunhildrud. Laser communicator. Copy right: Nordnorsk Vitensenter.

[40] Lawrewnce Manion Louis Cohen and Keith Morrison. Reasearch Methods in Educations. Routledge, New York, 8th ed edition, 2018.

[41] Cato R. P. Bjørndal. Det vurderende øyet : observasjon, vurdering og utvikling i pedagogisk praksis. Gyldendal akademisk, Oslo, 3. utg. edition, 2017.

[42] Allison Augustyn. GPS adventures: A guide for teachers and students. `https://app.box.com/s/vrmdgrbs597fh6xcw093umv61voy2xf7`, 1986.

Appendix

A Method: Teaching Setup

The detailed teaching program according to the different subject groups TA, TB, A and B given in appendix A.1 with the different teaching elements given in A.2

A.1 Lesson plan program divided subject group

A.1.1 Group Tromsø A & B

Program for group Tromsø A & B

DAY 1:

TIME PLAN:		ACTIVITY:
5 min	0900-0905	Attendance / Welcome
45 min	0905-0950	Presentation and information about the Talent-center
30 min	0950-1020	Name Games to break the ice: Classical name games
10 min	**1020-1030**	**Break**
45 min	1030-1115	Get to know games (with focus on the theme): Activity: Back-to-back drawing chain Activity: Different way to communicate
15 min	1115-1130	Data collecting pretest
60 min	**1130-1230**	**Lunch**
45 min	1230-1315	Introduction to communication and wireless communication: Discussion: Different types of communication Discussion: The Golden Record Activity: Paper cup phone
10 min	**1315-1325**	**Break**
20 min	1325-1345	Introduction to Micro:Bit programming
45 min	1345-1430	Activity: Programming Micro:Bit wireless communicator
10 min	**1430-1440**	**Break**
20 min	1440-1500	Introduction to Satellite system: Activity: Triangulation of Satellites
30 min	1500-1530	Looking at the Satellite around the earth in a full dome theater
30 min	1530-1600	Movie: We Are Astronomers - full dome show
Total: 420 min		

DAY 2:

TIME PLAN:		ACTIVITY:
5 min	0900-0905	Attendance
20 min	0905-0925	Introduction to the day: Starter Activity: "Which one do not not belong?" Demo-movie of the days mission (Micro:bit Robot Ball)
30 min	0925-0955	Preparation to to: Distribution of equipment, log-in, etc.
15 min	0955-1010	Introduction to the mission
10 min	**1010-1020**	**Break**
10 min	1020-1030	Introduction to the wireless control programming
45 min	1030-1115	Programming of wireless control and testing
15 min	1015-1130	Student group presentation of their solution
60 min	1130-1230	**Lunch**
15 min	1230-1245	Class collaboration in creation of the game rules
15 min	1245-1300	Creating teams and introduction to accessories
60 min	1300-1400	Design, programming and construction of the robot
45 min	1400-1445	Robot Ball Tournament
10 min	1445-1500	Evaluation and Data collection posttest
Total: 360 min		

A.1.2 Group B, Bodø

Program for group Bodø

DAY 1:

TIME PLAN:		ACTIVITY:
5 min	0900-0905	Attendance / Welcome
25 min	0905-0930	Presentation and information about the Talent-center
45 min	0930-1015	Name Games to break the ice: Classical name games Get to know games (with focus on the theme): Activity: Back-to-back drawing chain Activity: Different way to communicate
15 min	1015-1030	Data collecting pretest
15 min	**1030-1045**	**Break**
45 min	1045-1130	Introduction to communication: Discussion: Different types of communication Discussion: The Golden Record Activity: Paper cup phone
60 min	**1130-1230**	**Lunch**
30 min	1230-1300	Introduction to communication and wireless communication: Demonstration: Vacuum-clock
35 min	1300-1335	Introduction to Satellite system: Activity: Triangulation of Satellites
10 min	**1335-1345**	**Break**
85 min	1345-1510	Activity: Laser communication system *made by the Science Center in Tromsø*
10 min	**1430-1440**	**Break**
30 min	1510-1540	Introduction to Micro:Bit programming
20 min	1540-1600	Activity: Programming Micro:Bit wireless communicator
Total: 420 min		

DAY 2:

TIME PLAN:		ACTIVITY:
5 min	0900-0905	Attendance
20 min	0905-0925	Introduction to the day: Activity: Starter Demo-movie of the days mission (Micro:bit Robot Ball)
30 min	0925-0955	Preparation to to: Distribution of equipment, log-in, etc.
15 min	0955-1010	Introduction to the mission
10 min	**1010-1020**	**Break**
10 min	1020-1030	Introduction to the wireless control programming
45 min	1030-1115	Programming of wireless control and testing
15 min	1015-1130	Student group presentation of their solution
60 min	1130-1230	**Lunch**
15 min	1230-1245	Class collaboration in creation of the game rules
15 min	1245-1300	Creating teams and introduction to accessories
60 min	1300-1400	Design, programming and construction of the robot
45 min	1400-1445	Robot Ball Tournament
10 min	1445-1500	Evaluation and Data collection posttest
Total: 360 min		

A.1.3 Group A, Alta

Used the same program as with subject group Bodø, see A.1.2, but with a reduction in total time length by 60 minutes on assembly day 2.

A.2 Teaching program elements

The approach to the different teaching elements in order of use in the teaching setup, where the discussions and demonstration are given in red and the student hand-on activities in green.

A.2.1 Communication and its different forms

Discussion: Communication and its different forms

Objective: Give the students an understanding of what communication is and the different forms we use to communicate.

1. **Discussion question:** *"What is communication?"*

   Definition of communication:
   Communication is the conveying or sharing ideas and information, though for example the use of language.

2. **Discussion question:** *"How do we communicate?"*

   Forms of communication:
   Humans communicates in many different ways. For example though normal conversation, written, with body language in form of gestures, etc, what all these example has in common is that they use our different senses as illustrated in figure 17

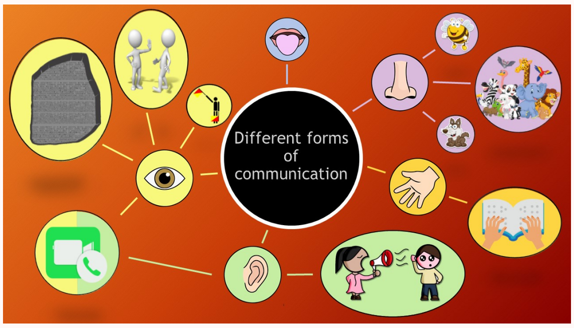


Figure 17: Example of different forms of communication in correlation with the senses

A.2.2 The Golden Record

Discussion: The Golden Record

Objective: To let the student reflect around how they would design a golden record and show that a communication system consist of more than only senders and receives.

Background information:
The golden record is a gramophone record that contains pictures, greetings and sounds from the earth, which was sent out on the space probes Voyager 1 and Voyager 2 in 1977.

Discussion question:
"If you were to try to make a golden record, how would you try to communicate?"

A.2.3 Paper phone

Paper Cup Phone

Objective: Give the students an understanding

Material:

- 2 paper cups
- 2 matches, paper clip or something similar
- Tread
- Pin
- Scissors

Activity:
The students work in pairs.

1. Push a hole with the pin through the bottom of the paper cups.
2. Thread the thread through the hole from the outside of the cup to the inside.
3. Tie the thread to the match on the inside of the cups.
4. Try the paper cup phone out.

Questions:

1. How does the tin-phone work?
2. What are the limitations of the paper cup phone?
3. Does it matter where the hole is placed?
4. Is it possible and are you able to create a network?

A.2.4 Vacuum clock

Demonstration: Vacuum clock

Objective: Give the student an indication of the difference between sound and electromagnetic waves

Materials:

- Vacuum clock
- Something that makes an annoyingly loud sound, for example an alarm clock (Sound device)
- Something that visually communicated though radio waves, example two micro:bit, one receiver and one sender, that displays something when receive a radio signal (Radio device)

Demonstration:
Show the difference of the sound level in normal atmospheric pressure and vacuum by placing the sound devise into the vacuum clock. After show that electromagnetic waves are not effected by placing the radio device into the vacuum clock

Explanation: The sound level of the sound device inside the vacuum clock will become lower and lower until it reaches vacuum and becomes silent. This is due to the fact that sound is an acoustic wave that needs an medium such as gas to propagate. The electromagnetic waves on the other hand do not need a medium to propagate and thereby reaches the signal the radio devise inced the vacuum clock unhindered.

A.2.5 Triangulation of Satellites

Activity: Triangulation with Satellites

The inspiration for the activity is taken from *GPS Adventures: A Teacher and Student Guide, Lesson 9: Satellite* [42]

Objective: Give the students an understanding of how electromagnetic signals are being used in GPS-technology, too find a given location through triangulation.

Material:

- Locations point sheet
- Location points
- Tread (up to 1 m)
- Scissors
- Small ruler (max. 15 cm)
- (phone/computer)

Preparation:

1. Create an location point sheet with 15 or more points, where three of the points will be used as satellite points, some of the points will be used as the actual location and the rest as decoys.
2. Choose which three of the points that will be used as satellite locations and which points that will be used as location points, see figure 18. Measure the distance from the satellite points to the location points and prepare the clue sheet. For example as shown i figure 19, for Point 22: 9.5 cm form Satellite A, 23 cm form Satellite B and 18 cm from Satellite C.
3. Lastly prepare something that is going to represent the different points. For example folded sticky notes for each of the different points, where the decoys ate empty and only the correct location points indicate that it is correct. For example have written coordinates in them.

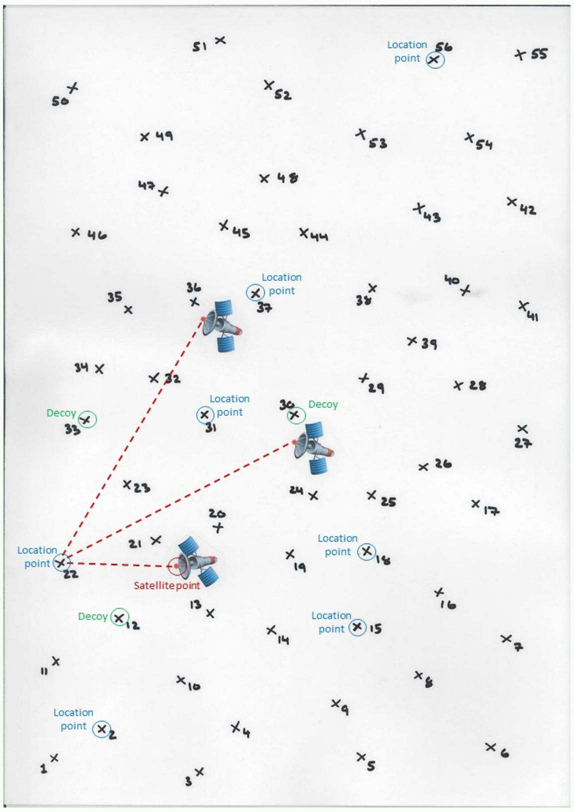


Figure 18: Example of a location sheet belonging to activity *Triangulation with Satellites*, with location points and decoys market on

SATELLITE CLUE SHEET:

Where are you?

- You are 9.5 cm from one of the satellites
- You are 23 cm form another satellite
- You are 18 cm form the last satellite

With use of triangulation can you find at which point on the location-sheet you reside?

Figure 19: An example of the clue sheet for activity *Triangulation with Satellites*

Activity:
Break the students into groups 2-4 in each group.

1. From the clues triangulate and find your location point.
2. Check if you are correct, by finding the belonging sticky note
3. Find out where you are.

Bonus Question:

- How mush time would it take for the signal to travel from the location point to the closest satellite point?

Alternative:
Write the clue-sheet in time instead of distance and let the students calculate the distance them self, where the speed will be the speed of light.

A.2.6 Wireless Communication with Micro:bit

Activity: Micro:bit Wireless Communication

Objective: Program a micro:bit that can send and receive a simple massage.

Materials:

- 1 Computer (with micro-USB)
- 2 micro:bit
- 2 battery packet for micro:bit

Activity:

1. Program a micro:bit that can send and receive a simple massage.

Hint: See lesson "Micro Chat" on Makercode.com

Variations:
Program the micro:bit to send and receive more complex massages. For example program the micro:bit to send and receive massages though morse code or a more complex text massage.

A.2.7 Starter activity

Starter activity: Which one do not belong?

This starer activity was created by Skaperskolen [?]
Objective: To show the student that their do not exists just one correct way to solve a problem.

Activity:
Choose one of the four picture and argument for which one do not belong?

Figure 20: Which one do not belong? *Figure from the presentation about the robot mission created by Skaperskolen []*

A.2.8 Robot ball

Activity: Robot ball

The activity is crated by *Skaperskolen* [38] **Objective:** Give the student practicable knowledge in the programming of a wireless communicator

Materials:

- 1 Computer (with micro-USB)
- 1 bit:bot
- 2 micro:bit
- 1 battery packet for micro:bit
- servos with the standard connection
- cutting equipment (Scissors, knives, cutters)
- building equipment (Thick carton, paper, popsicle stick, flower sticks, paper Fasteners, paper clip, binder clips, rubber bands, etc.)
- tape
- arena (a marked arena preferably with walls)

Mission: write a program for micro:bit that work as a radio-control to make the Bit:Bot minimally drive forward, stop and turn. Thereafter create with the extra given extra material such as paper, popsicle sticks, etc. in addition to servos a bit:bots robot which will have the ultimate advantage in the robot ball tournament.

B Method: Data collections templets

B.1 The full Talent Center evaluation survey

Questions	Answer Options				
I have learned a lot in talent assembly	strongly disagree	partly disagree	neither agree or disagree	partly agree	strongly agree
I think what we have done at talent assembly is relevant to my learning of subjects at school	strongly disagree	partly disagree	neither agree or disagree	partly agree	strongly agree
I sometimes thought the academic level was too HIGH in this talent assembly	strongly disagree	partly disagree	neither agree or disagree	partly agree	strongly agree
I sometimes thought the academic level was too LOW on this talent assembly	strongly disagree	partly disagree	neither agree or disagree	partly agree	strongly agree
I have become more motivated in mathematics and science because I have participated in talent assembly	strongly disagree	partly disagree	neither agree or disagree	partly agree	strongly agree
Group and collaboration tasks have worked well for me	strongly disagree	partly disagree	neither agree or disagree	partly agree	strongly agree
I have had a good time socially at talent gathering	strongly disagree	partly disagree	neither agree or disagree	partly agree	strongly agree
I have made new friends among the others at the talent gathering	strongly disagree	partly disagree	neither agree or disagree	partly agree	strongly agree
I enjoyed the food at the gathering	strongly disagree	partly disagree	neither agree or disagree	partly agree	strongly agree
I liked the way we stayed (if applicable)	Yes	No			
Have you become acquainted with, or interested in, any new topics in science and mathematics at talent gathering? (Write only keywords)					
Do you think that participating in talent gatherings has influenced you in what you want to study in the future?	Yes	No	I don't know		
If you are going to study when you finish high school, what kind of subject/line do you think you will apply for?					
I enjoyed these activities at the talent gathering					
I did not like these activities very much					
At the next gathering, I want more of the following activities or topics					
Do you have any other comments or feedback?					

B.2 Result: After action log template

AFTER ACTION LOG	
Subject group:	**Day:** _______
Date: ____________________	
Description of the subject group: Pedagogue:	
Summary of what happened	

Figure 21: The after action template

C Results from the observation in form of After action logs

The after action log in order of the assembly execution; Tromsø A, Tromsø B, Bodø, Alta.

C.1 Group TA, Tromsø A

<table>
<tr><td colspan="2"><u>AFTER ACTION LOG</u></td></tr>
<tr><td>Subject group: Tromsø A</td><td>Day: 1</td></tr>
<tr><td colspan="2">Date: 23.09.202</td></tr>
<tr><td colspan="2">Description of the subject group:
A total of 20 students (10 boys, 10 girls) was offered a place at the Talent Centre group Tromsø A and came to the assembly. Some of the students indicated of being type 1.

The student was seated in groups of four students, where they choose their seat themselves.

<u>Pedagogue:</u> two pedagogue (including the author) coexistent in the room up until the last hour where only the author was left.</td></tr>
<tr><td colspan="2">Summary of what happened</td></tr>
<tr><td colspan="2">The assembly was held at the Science Centre in Tromsø, within their computer-lab. During breaks had the student access to the rest of the museum and its exhibition.

This was the first time the teaching program was implemented.

The student was a quiet group in the beginning, but the ice seamed to break after the get-to-know activities. Especially the back-to-back drawing chain activity, where not a single group ended up with the picture they started with. This gave the indication to make the more relaxed and not so scared to make mistakes (observation by the author).

During the discussion around the golden record was the students very interested in what type of message they would send and how it would be prevised. One thing that ended up especially being discussed was if a smile with teeth would be perceived as threatening. The animal kingdom was brought up as an argument for this.

Some exercises and parts of the program ended up tanking more time than planed and as a result for this was the Triangulation of Satellites dropped. To make up for this was it discussed a bit deeper in the planetarium.

From the movie we are astronomers at the end of the assembly stared the students a discussion around the access of information in the digital edge due to digital communication and how critical thinking is important. This was not at all something that was thought about during the planning process of the teaching setup.</td></tr>
</table>

AFTER ACTION LOG

Subject group: Tromsø A	**Day: 2**
Date: 24.09.2022	

Description of the subject group:
A total of 20 students (10 boys, 10 girls) was offered a place at the Talent Centre group Tromsø A and came to the assembly.

The student was seated in groups of four, where they choose their seat themselves. They worked during the day 2 of the assembly in pairs as they sat. The pairs was mixed into different teams for the tournament, to give the student the opportunity to get to know more of the students in the class better.

<u>Pedagogue:</u> two pedagogue (including the author) coexistent in the room

Summary of what happened

The students were very eager for the main mission, thereby needed they needed to be pushed a bit in the starter exercise, which one do not belong. The students were in different levels in ability around programming and had different solution in the way they attached the problem. One pair who was very interested in programming used especially a lot of time to try to figure out a way to hack their competition. The building process starter not until after lunch and thereby the rules for the tournament wasnt established by the class until then. The class decided that during the tournament were hacking not allowed which made the extra work the pair of students did sadly not usable.

A little while before the tournament was there several problems with that the micro:bit radio controller would not communicate with bit:bot. This opened up the discussion again of what could hinder the electromagnetic waves to travel and how they behave in different mediums.

Due to the fact that there was a problem with the communication between the micro:bit radio controller and the bit:bot was the tournament not quite fair, but it gave the students an opportunity to work on trouble solving.

The building process was a little bit short during this assembly, thereby will it be extended for the coming assemblies.

C.2 Group TB, Tromsø B

AFTER ACTION LOG

Subject group: Tromsø B	**Day: 1**
Date: 27.09.2022	

Description of the subject group:
A total of 21 students (16 boys, 5 girls) was offered a place at the Talent Centre group Tromsø B and came to the assembly. One of the students became sick during the day and had to leave early.

The student was seated in groups of three or four students, where they choose their seat themselves.

Pedagogue: two pedagogue (including the author) coexistent in the room up until the last hour where only the author was left.

Summary of what happened

The assembly was held at the Science Centre in Tromsø, within their computer-lab. During breaks had the student access to the rest of the museum and its exhibition.

This group consisted of mostly boys where several had an interest and worked with the team before, thereby wasnt as engaged in the assembly do to that they had done something similar before (from a talk between the author and some of the students).

After breaking the ice with the get to-know activities and a quick discussion on what communication is and how we humans communicate with the help of our different sequences continued the discussion into the golden record. This class connected this discussion with previous where they really started to discuss the formats of the massage should use how many seances as possible since it wasnt necessarily garneted at aliens would mainly use sight and hearing as us humans. To further this argument was it discussed in how especially insects such as bees and ant used smell and pheromone to communicate. One student suggested to send a chocolate bar in a addition to other information on something from the golden record form 1973. It wouldnt go bad since it would be in space which is both colder that your freezer and in a vacuum. This point was again brought up during the demonstration with the vacuum clock, where the students really wanted to see what would happen to a chocolate bar in a vacuum. Sadly, there was any accessible and it could only be speculated at.

This class was their time to walk through the whole program. Thereby, was the Triangulation with Satellites activity tested on this class for the first time with the version where the students had to calculate the distance between the satellites marked on the paper dependent on a given time in the clue sheet.

This class seamed more eager to leave at the end of the day and there was no discussion after the move then he assembly time ran out as there was with group TA, Tromsø A.

AFTER ACTION LOG

Subject group: Tromsø B	**Day: 2**
Date: 28.09.2022	

Description of the subject group:
A total of 20 students (15 boys, 4 girls) came on day 2 of the assembly.

The student was seated in groups of four, where they choose their seat themselves. They worked during the day 2 of the assembly in pairs as they sat. The pairs was mixed into different teams for the tournament, to give the student the opportunity to get to know more of the students in the class better.

Pedagogue: two pedagogue (including the author) coexistent in the room

Summary of what happened

Even though some pf the students had not been as engaged in the day 1 of the assembly, since the day had a bit more theory everyone threw themselves into the main mission of day 2, where they had the chance to let their creativity shine.

The time for introduction, show and tell of their solution the simple programming version and discussions was shorten a bit in favour of the bounding and designing process with an overall presentation of their bit:bot in the end.

The rules were agreed upon and the students were given a half hour to start the design and building before lunch. 3 of 4 teams wanted to shorten their lunch break, which they were allowed to continue building. Especially the girls, who had very little knowledge and

experience in programming before the assembly (from a talk with the students).

The tournament went smoother than with group TA, Tromsø A, with no problems in the communication of between the bit:bot and the micro:bit radio controller. And the student seemed happy with the day (observation by the author).

C.3 Group B, Bodø

<table>
<tr><td colspan="2" align="center"><u>AFTER ACTION LOG</u></td></tr>
<tr><td>Subject group: Bodø</td><td>Day: 1</td></tr>
<tr><td colspan="2">Date: 13.10.2021</td></tr>
<tr><td colspan="2">Description of the subject group:
There was total of 17 students at the assembly, where 12 were boys and 5 were girls. Several of the students gave the indication of being type 1.

The students choose where they wanted to seat themselves in three groups of 4 student and one group of 5. Most of the students didnt know each other except for the group of 5 students, which was all from the same area.

<u>Pedagogue:</u> two pedagogue coexistent in the room (including the author)</td></tr>
<tr><td colspan="2" align="center">Summary of what happened</td></tr>
<tr><td colspan="2">The assembly took place in a normal classroom at a school, which none of the students belonged to. This year was the first time the Talent Centre was offered to the students in Bodø.

After the get to know activities seemed the students more conferrable with each other, several commented that they where a little bit nervous before coming to the assembly.

The students were very active in the discussion in the small groups and after a little push from the educator (in this case the author) flowed the discission seamlessly in the classroom for the group as a whole, where several took initiative to participate. In the discussion around the golden record was one group of students was focusing more on which format the massage should have and concluded (between them) that they would do as many formats as possible ass possible in form of a CD, electronically on a hard disc, USB or something similar and in dorm of a transmitter that could transmit the massage with Bluetooth or something similar (the students had not acquired the term electromagnetic waves jet). The other three groups discussions lead to more around what they would send and how it could be preserved by an outsider.

During the activity paper cup phone shined the students motivation and interest in science. The students started to build their own network from the paper cup phone as the illustration in figure 22 describe, without any encouragement from the educator (in this case the author). They even started discussions around why there was a difference in the clarity of the sound depending on which cup was spoken into. The students conclusion was that the cups connected to the primary line had the best sound and as more and more cups the sound propagated the more diluted it became really difficult to make out the sound but still be able to hear it.

The students created a competition between the groups to during the activity triangulation with satellites to see how managed to solve the task first.</td></tr>
</table>

During the activity where the students was tasked to build a laser communicator, managed all four groups to complete the task a build a working one, but it there used a little extra time on to test the communicators. Due to the extra time needed something to give, so after a vocal survey with the students indicated them that they were familiar with micro:bit and makercode and thereby was the introduction into micro:bit skipped over.

One thing that was interesting with this group was that there were not that instated in breaks. This was probably due to the fact we only had access to a normal classroom, and it was raining heavily outside.

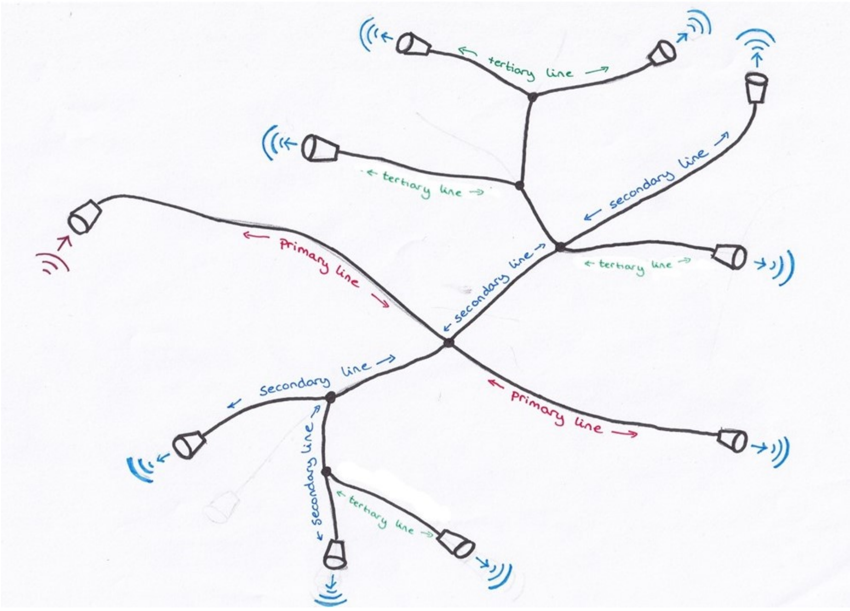


Figure 22: An illustration of the paper cup phone network created by subject group B, Bodø

AFTER ACTION LOG

Subject group: Bodø	**Day: 2**
Date: 14.10.2021	

Description of the subject group:
There was total of 16 students at the assembly on day 2, where 12 were boys and 4 were girls. This is one less than the day before due to sickness. One student also had to leave before the day was over.

Pedagogue: two pedagogue coexistent in the room (including the author)

Summary of what happened

Day 2 of the assembly went very smoothly. The students were a bit slow in the start-up activity (4 picture, 1 wrong).

The during the rest of the program was the students very engaged. The students worked in pairs two, were the got to choose their own partner, but for the teams was two and two pairs randomly mixed up by the educator (in this case the author). Again, were the student not much interested in breaks. Every team wanted to start building again as soon as possible after lunch, and where free to do so a half hour into lunch. The tournament was quite intensive, where one student managed to get away with hacking the others, even though the class had agreed as a whole to not hack each other, but would only be disqualified from the tournament if caught. This student wasnt caught and only admitted it to the author after the assembly was over.

Again was it raining heavily outside, which might be the reason for students disinterest in breaks.

C.4 Group A, Alta

AFTER ACTION LOG	
Subject group: Alta	**Day: 1**
Date: 21.10.2021	
Description of the subject group: The subject group consisted of 17 students in total 16 boys and only 1 girl. There was one student that this author will classify as a type 5 student and one student arrived very late. Several of the students participated in the Talent Center the year before. The students was seated in small groups of four students (one group of five student) based on the experience two of the pedagogues had to most of the students, since several participated in the Talent Center the year before Pedagogue: three pedagogue coexistent in the room (including the author) and one that came and went.	
Summary of what happened	
The assembly took place at the department branch in Alta of the Science Centre in Tromsø, which has an exception room (where breaks took place) in addition to a classroom/laboratory (where the teaching took place). We manage to go through the whole teaching program for day 1. It was a tight program, but it didn't feel that we had to sprint through the program. This was mostly since this group was the least active and engaged in the discussion than I have experienced by compared to the previous assemblies (Tromsø A & B, Bodø). Since so many few of the students engaged in the discussion became it a lot more talk and reflections form the me (the educator). On the other hand, was the students very engaged in the practical activities (paper phone cup and triangulation with Satellites). Two of the students decided to the test out how long they could make the string and let the sound still travel. This in turn activated the whole class. They ended up with about a 30 m long string (because there wasn't any more string left), which went out the classroom down some stairs and out of the building. what the students observed was that they still just could make out some sound as long as the sting was really tight. Even if the students werent as active in the discussion in the classroom continued, they their own discussion around the paper phone cups during the lunch break. Under the laser communication activities manage we only to get one of four communicators to work. This opened for the opportunity and discussion of sources of error and trouble shooting in experiments and what we can learn from the mistakes that might accrue. The assembly ended with an introduction of micro:bit and makercode, which the students had a good amount of pre-existing knowledge of the general use, but was a bit challenge when it came to the understanding and use of variables in coding. The was a parent-teaching conference after the assembly where the author was an observer to. Parents of two different students commented that: *"the students was extremely happy with the day as they, unlike after a normal school day, since had been academically challenged and learned something new which apparently hadn't happened in a long time."*	

AFTER ACTION LOG

Subject group: Alta	**Day: 2**
Date: 22.10.2021	

Description of the subject group:
In total was there 17 students at the assembly, where 16 was boys and 1 girl. A few of the students left and came back throughout the day due to vaccinations (in total 3 students), in addition to one student that had to leave before the day was over.

The student was seated in predetermined groups of 4 students and one group of 5 based on the experience form day 1. The students worked in groups of 2 except one of 3 students thought the day.

Pedagogue: two pedagogue coexistent in the room (including the author) and one extra during the tournament.

Summary of what happened

The students were very quiet again during the starter activity ("4 picture, 1 wrong"), but became very eager and worked quickly when the main challenge was started. Most of the students was finished programming the micro:bit radio controller rather quickly, but had some problems when challenged to see if they could improve the computer program.

Under the building and design process created most of the groups strategies on what role the different bit:bots on the team should how and how the design should reflect this. The strategy discussion started before lunch and several of the students continued to discuss throughout the lush break and chose to shorten their break to continue to work of the design and building. The group that was observed communicated, deliberated, and discuss the most ended up as the winners of a very intense the tournament.

As the students left for the day gave, they the indication that they where very happy with the assemble.