MINIPROJECTS AND CONTEXT RICH PROBLEMS
Case studies with qualitative analysis of motivation, learner ownership and competence in small group work in physics

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Abstract
This thesis reports case studies of students working with context rich problems (CRP) and mini projects (MP) in physics in an upper secondary school class and in a physics teacher education class at university. The students report a big shift from physics in secondary school as fun and easy, to physics in upper secondary school as boring, difficult and with lack of time for reflections and physics talking, but they also found physics as interesting in itself. In order to study how group discussions in physics influence the students learning and to study the phenomena of students’ ownership of learning (SOL) we introduced CRP and MP. We video recorded five groups with 14 teacher students at university in the end of 2002, and five group with 15 students at upper secondary school during the beginning of their second physics course in the spring term in 2003. MP and CRP in physics were used as instructional settings in order to give students possibility to strengthen their holistic understanding and their possibilities to ownership. When students get the opportunity to manage their own learning and studying by open-ended tasks in physics, without the teacher determining all details of the performance, this gives more ownership of learning. The advantage of MPs and CRPs from the student’s point of view is more freedom to act, think and discuss and from the teacher’s view, to get insights of the students’ ability and how they really think in physics. The ownership is found to be crucial for motivation and development of competence.

Students’ ownership of learning (SOL) is the students’ influence/impact to affect tasks and the learning environment in such a way that the students have a real opportunity to achieve learning of physics.

Students’ ownership of learning (SOL) is found at two levels:

Group level: At the start of a task the SOL is determined by the design of the task. The choice of task, the performance (when, how, where), the level of result and presentation and report have to be determined by the students themselves.

Individual level: A person’s experiences and anomalies of understanding have created unique questions that can create certain aspects of the task that drive this person to be very active and highly motivated. This gives the person a high individual ownership. We developed hypotheses concerning the relation between ownership, motivation and competence and we see some evidence in the cases reported in this thesis. The importance of exploratory talks to enhance learning, and to see aspects of communication as part of the motivation are discussed in the model of ownership, motivation and competence that is proposed.
Dedication
To all students and student teachers I have met who struggle with physics learning, with respect and confidence in your ability.

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Ethics
The students and student teachers in this study do not perform by their real names. They have signed an agreement and given their permission for me to use tape-recordings, video-recordings and other data collected during the course in scientific purposes for the project reported in this thesis. My intention is to use the data in a way, that will benefit students to an improved physics teaching, and to strengthen the respect for their individual qualifications and struggle in learning physics.
Definition of Terms

SOL Students’ ownership of learning
SOL is the students’ influence/impact to affect tasks and the learning environment in such a way that the student has a real opportunity to achieve learning of physics. This definition can be found within the thesis in more detail.

MP Miniproject
MP is a task or experimental problem or inquiry given in order to strengthen the competence in physics. The MP could be given in different degrees of freedom, and for different time periods. We used MP that were effected during two weeks, and with a list of proposed MP to select from. The performance of the MP was on the students’ responsibility and choice, and forms of report and presentation were decided by the students.

CRP Context Rich Problems
A context rich problem is a physics problem in the context of a story, given to a small group of three or four students. The CRP is by that different from an ordinary textbook problem. The design of the problem encourages students to use a logical problem solving strategy instead of plain formula driven random search strategy.

PBL Problem Based Learning
Problem-based learning is both a curriculum and a process. The curriculum consists of carefully selected and designed problems that demand from the learner acquisition of critical knowledge, problem solving proficiency, self-directed learning strategies, and team participation skills. The process replicates the commonly used systemic approach to resolving problems or meeting challenges that are encountered in life and career. The students assume increasing responsibility for their learning, giving them more motivation and more feelings of accomplishment, setting the pattern for them to become successful life-long learners. Many instructional designs are inspired by PBL, without taking the step to change the whole curriculum.

INT Internal teaching
By internal teaching we mean the phenomena when a student in the small group finds herself/himself competent to teach a peer student who seams to have lack of understanding of some conceptual or contextual (holistic) understanding or laboratory or mathematical skill.

EXT Exploratory talks
Douglas Barnes (Barnes 1973) explains exploratory talks in this way:

These discussions are very different from what usually takes place when a teacher faces a whole class. It is not only that the children are using language in a more exploratory fashion than often occurs in relative formality of the full class. It would be fair to say that they are using a far wider range of speech-roles than full-class discussion usually allows – questioning, encouraging, surmising, challenging, extending, and so on. This is possible because they have between them taken over control of the learning activity. In order to manage this they have had to collaborate: one has to draw in another; a third uses ideas from both the others. They have had to signal to one another not only the ideas they want to put forward but also invitation, encouragement, acceptance, tactful disagreement: they have had to set up an appropriate mode of communication as well as deal with the task in hand.
Chapter 1  Introduction and situating the study

1.1  A historical perspective of teaching physics in school – from revolution to tradition

Science and technology have been powerful tools for humanity to have impact on society. With technology we have been able to improve and take some control over living conditions and public welfare and with science and physics we have tried to understand and explain reality in terms of, initially, teleological and later, causal connections. Science has been revolutionary in its character. When you light a fire you first take stick of dry, resinous wood to get a small fire going but soon you can see how it grows and bursts into big flames. In the same way science has initiated a development of society that nothing could stop. Of course, there are persons that stand out with a passionate interest in a specific matter that drives this progress. The circumstances in which these people could reach such results are very interesting.

To understand my own interest of student ownership, motivation and competence in physics I am forced to try to understand the historical connections and to get a historical perspective of the teaching of physics. In this introduction I will give a picture of how knowledge in physics and the teaching of physics took shape in Swedish schools at the end of the nineteenth century and what happened next. By following the development of the Swedish school the picture of how revolutionary physics was is strengthened.

The entrance of chemistry and physics into the universities was slow and succeeded only by confronting and winning the battle against the representatives of classical education with Latin as the language of communication.

It was the usefulness of science that finally won the victory over the superciliousness of classical education at the old universities and that enabled Chalmers and KTH to develop from technical institutes to acceptance as universities, city church schools (läroverken) to get a natural sciences line and Swedish elementary schools (folkskolan) to get science into the timetable.

It can seem strange that physics is now seen as the subject that is the most abstract and theoretical in Swedish upper secondary schools and is doubtless regarded as the most conservative in its teaching strategies. A flashback to the first physics textbooks surprised me as they look almost the same as today’s. How could this happen? And what is the future for physics in school?

I do not claim to give an entire description of the history of physics teaching but I will, as an introduction to my study “Miniprojects and contextual problems – ownership, motivation and competence in physics small group work”, give glimpses to high-light why we have to continue into a new age of physics teaching.

When I follow the time-line given in Physical Sciences Information Gateways (a link from JISC\(^1\)) natural science discoveries are given from 2000 BC to 2003 AD. I take a sum of all discoveries during each hundred year and plot the cumulative frequency against time. The remarkable increase of science events versus time can be seen in figure 1.1.

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1 “The Joint Information Systems Committee (JISC) supports further and higher education by providing strategic guidance, advice and opportunities to use Information and Communications Technology (ICT) to support teaching, learning, research and administration. JISC is funded by all the UK post-16 and higher education funding councils.”
Fig. 1.1: Natural science time-line: Number of events and discoveries in every century. Data from the Time-line given in Physical Sciences Information Gateways. See www.psigate.ac.uk/newsite/science_timeline.html.

Figure 1.2 shows the corresponding trend of events in physics, that is discoveries and publications, and shows the same exponential development curve. These curves mediate one of the realities that physics teaching has to meet: To learn has been to take in earlier experiences and knowledge and to proceed from this and continue with one’s own work to find new insights and make new contributions. For hundreds of years people have kept themselves up to date with most of the knowledge of the time. This is no longer possible for anyone and the use of artefacts becomes necessary to handle all the information.

Fig. 1.2: Physics time line. Number of discoveries cumulative, per century. See www.psigate.ac.uk/newsite/science_timeline.html.

How should we look upon physics teaching in the light of this enormous increase in the mass of knowledge? Where are we going? Staffan Selander writes about approach to physics knowledge and cultural framework:

Increasingly the rhetoric concerns the individual, free choice, joint responsibility, participation in negotiations and decisions and so on. From a general perspective the understanding of school and the objectives for schools has changed. Looking more closely at physics as subject, there has not been a corresponding displacement in the curriculum – science education
researchers (to a large extent the same people write the main elements of the curriculum and the textbooks) have succeeded in preserving a strong tradition and a strong subject delimitation. In any case changes can be seen in schoolbooks and that could mean that a new generation of writers in the subject of physics pedagogical texts are in the arena. This can be a sign that more radical changes are coming in the cognitive self-understanding of the whole operation of the school. (Translation from Swedish) Selander 1998.

1.1.1 The School development during the Catholic Middle Ages
(Richardson 1994; Sandström 1995; Egidius 2001)
Sweden was an agrarian society with self-sufficiency during the main part of the Middle Ages, where learning outside the family farm (holding) not was necessary. With Christianity, increased trading and a beginning of a class society, city schools developed to teach writing and calculating and to do some Latin. The Catholic Church demanded an educated priesthood. Internal education inside the church was given in the monastic orders from the thirteenth century and in cathedral cities, with cathedral chapters ruling church life, choir schools were developed. Boys and men came to the universities to start their studies directly, even if, as in Lund, Uppsala, Linköping and Skara there were choir schools. These schools gave a secondary school education that prepared students for studies at the University in Paris. During the fifteenth and sixteenth centuries the burghers of the cities in Norden became increasingly powerful as new technology and new knowledge became available. The art of printing led to ancient texts becoming available in their original languages.

1.1.2 The School changed during the Reformation
(Richardson 1994; Sandström 1995; Egidius 2001)
The educational monopoly of the Catholic Church was challenged more and more and from the sixteenth century wealthy merchants increasingly influenced society. With the Reformation convent schools disappeared and under Gustav Vasa Sweden developed into a nation-state with an established national church. Our first curriculum is from years 1511, 1571 and year 1611. There were 22 schools in Sweden in 1560. The purpose of teaching is to give people knowledge of Christianity. The church was responsible for reading of the catechism. In the beginning of the seventeenth century Gustav II Adolf reorganized some choir schools into secondary grammar schools (gymnasier) after the German tradition. These royal schools were called gymnasier and they educated Lutheran priests. They became a part of the exercise (wielding) of power. The Gymnasier in Västerås 1623 and Strängnäs 1626 became provincial university colleges. When Johannes Rudbeck (1581-1646), the bishop of Västerås and founder of the first gymnasium there, was installed as a professor in Uppsala 1604 he hold a speech about “the usefulness and necessity of science and schools and expressed:

We see that if the educational institutions are in good shape the state will grow, and are in every way happy, but if the former break down then the latter will follow soon enough. It seems possible that the books and thoughts of Francis Bacon (1561 – 1626) were available in Sweden at this time. Bacon’s intention was that the first purpose of science was to improve the human conditions on earth which was a revolutionary

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thought in that age. In the same way Galilei’s (1564-1642) thoughts of the heliocentric word picture must have reached Sweden at this time. Representatives of this new view of the world had contend with the theologians at Uppsala University as, at that time, belief in the authority of the canon law came above free thought and free research.

Gustav II Adolf invited Amos Comenius (1592 –1670) to reform the Swedish Education system. Comenius’ lifework, Didactica Magna, was completed 1632 but was first published in 1657 in Amsterdam. The principal points of his pedagogical methods in Didactica Magna are summarized (Comenius 1632):

- The teaching content has to be adapted to the student’s comprehension
- Instruction must start with a common orientation of the essential parts of the content in order to give the student a comprehensive overall view of content
- Instruction must start with the simple and go on to the more complex
- Instruction must be concrete, i.e. set out from object lessons. Only by starting in sensuous experience can man go forward to true logical knowledge, true intuition and experience God.

These teaching methods are of immediate interest. It is also thought-provoking that Comenius recommended teaching to both sexes. It took more then two hundred years for this to happen, but he was clear about this in his time.

In Sweden from the curriculum year 1611 there were provincial schools and choir schools with apologist classes in mathematics, run by the merchants for their sons. In the choir schools and in the gymnasium you had by medieval practice the first four years in trivium: latin grammar and literature, dialectics (the art of argument) and rhetoric (the narrative art). After the year 1649 there were trivium schools, gymnasier and academies.

In the seventeenth century we see the establishment of a structure of schools, traces of which can still be seen in the 21st century; the main task for trivium schools was four years of elementary schooling with a class-teacher system, and the gymnasium was four years to prepare for university studies in a system with teachers of special subjects. This classical secondary grammar school (with Latin) was the dominant school for more then two hundred years. The apologist school was in fact a third form of school: one year in trivium school and two years in apologist class. This was a forerunner of junior secondary schools.

The next school reform, 1693, included a regulation for a test of knowledge to be made before going from gymnasium to academy. The reason for this was that earlier it had been acceptable for the sons of the nobility to go directly to university without first going to school. Uppsala University, established in 1477, included only a theological faculty. After the founder, bishop Jakob Ulvsson died in 1515 the university was closed down. The university was re-established in 1593, but not until 1620 were there funds for more students. In the 1630s approximately 1,000 students were at the university. Anders Celsius became a professor of astronomy and Carl von Linné professor of medicine at the end of the 1720s. (The first female student was accepted in 1872.) In 1630 Gustav II Adolf laid the foundations of a mining institute that was named Bergskollegium (the Mining College) after re-organization in 1644.

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3 apologist Greek word meaning to render an account of something, students learned bookkeeping
The purpose of this was to support the exploitation of Swedish mineral deposits. Chemistry in Europe during the eighteenth century was dominated by both theoretical and practical work. The foundations of a great number of private enterprises were laid in a higher technological education, such as a veterinary education and schools in specialized training. Industrialization had started in England and modernism was initiated.

Carl Mitcham says in his book “Thinking Through Technology” that there have been three attitudes towards technology in history, and the first attitude seen is technology as “necessary but hazardous”, that expresses suspicion of the technological progress. Mitcham finds this view as describing people who turn away from God when they choose technology, as exemplified with the myth of the tower of Babel.


With the Renaissance and the Age of Enlightenment Mitcham finds there is the second attitude; an **authorization** from God to use nature by means of technology. Society will blossom and the public welfare will increase.(Mitcham 1994)

### 1.1.3 Learning during the eighteenth century

Characteristic of the eighteenth century was that research and progress in science were often made by discoveries and inventions by people not directly connected to the universities but who were invited to the universities as experts. In Sweden, for example Scheele was invited into the Royal Swedish Academy of Sciences (instituted 1739) as a pharmacist. He was a chemist with a worldwide reputation. He stayed as a pharmacist in the town of Köping until he died in 1786.

James Watt was an instrument maker at Glasgow university when he got the job of repairing a demonstration modell of Newcomen’s steam engine to make it function better as it never worked well enough.(Nielsen 1992) He solved the problem and his revolutionary invention was one of the stepping stones in the industrialization of England. With Boulton’s money the company Boulton & Watt provided steam engines with power of 5 – 20 hp.(Nielsen 1992)

Michael Faraday studied scientific literature and repeated electric and chemical experiments he found in the books. He was permanently employed in a book store. He became a member of a scientific society, City Philosophical Society, where he was commissioned to cover the nature of electricity. When, at the end of the eighteenth century, he settled down in London he came into contact with (at the open lessons at the Royal Institution) Humphrey Davy, a professor of chemistry. Faraday became Davy’s laboratory assistant. He later solved practical problems of water pollution in the Thames for the Royal institutions and improved production methods for glassware.
and China. Faraday discovered electromagnetic induction in 1831 and he designed the first generator.

For somebody's learning to be fruitful in action and in new ideas there has to be knowledge, time and a burning interest but also the challenge of problem solving and a creative spirit (genius). Most important seems to be the self-creativity and self-study, but I presume that there must also be communication with others who act as sounding boards and make evaluations.

In the eighteenth century in Sweden the class society gave way to a growing middle class and there were the beginnings of secularism.

In 1745 the universities got faculties for physics and mathematics. Some proposed new subjects for gymnasier and trivium schools, physics, natural history, economy and mathematics but the church prevented this. By 1750 of the 4,200 boys in Swedish only 30 came from the nobility. Teaching was instead undertaken by private tutors. Also in 1760 up to 80% of the boys from the nobility at university were taught by private tutors.

1.1.4 The progress of physics teaching at Uppsala University
(Beckman 1965)

The teaching of physics started in the 1486 by Petrus Olai who gave lectures on Aristotle’s eight books in physics. Physics was then science in a wide sense and included botany, zoology and anatomy but not mechanics or optics. The fundamental principals; matter and form, time and space and the “four reasons” were discussed. In 1627 a Latin translation of Aristotelian mechanics came out as a textbook in Sweden and was used by the professor of mathematics, M.E. Gestrinius. This first textbook in physics had, as content, some simple machines such as the lever, the wedge, the pulley and the roller and this has been seen in mechanics textbooks up to the present.

The teaching was inspired by Cartesian physics and experiments. Andreas Drossander bought equipment on journeys abroad, for example an air pump, a thermometer and a barometer. In the eighteenth century there arose an interest in Newtonian physics, especially optics. A rising interest in experimental physics came with Anders Celsius’ research into the northern lights and with the precise observations of the magnet needle’s inclination, declination physics came to consist of accounts of series of precise measurements. From the year 1765 there is a 750-page course in physics “Elementa physices” written by the docent Nils Wallerius, who gave lectures in two or three periods a year and then for 8 to 10 hours in experimental physics to “many listeners”. In 1759 there was a new physics textbook, “Utkast till föreläsningar öfver Naturkunnigheten” by professor Samuel Duraeus. This textbook became the course literature for several decades. His successor, Zakarias Nordmark, had an interest in teaching and helped at approx. 70 disputations in mechanics and optics, (most of them with less then eight pages.).

A.J. Ångström was number one in laboratory experiments for students. From the spring term of 1862 the physics course could take 12 students. In 1887 the “Fysiska sällskapet” was established. Fysiska sällskapet held regular, frequent committee meetings where new works were reported and discussions were held about physics questions of immediate interest. These seminar classes became enormously important to the students. Manne Siegbahn re-introduced these seminar classes in 1920 in physics to students.
At the beginning of the twentieth century the course to get the grade “två betyg” in physics included an introductory course in the spring semester with three lectures a week with a final examination in May. After this the studies continued in the laboratory two days a week for two more terms in an individual’s schedule. The fourth and last term ended with a technical course and a demonstration course. In the demonstration course the student had, after two weeks preparation, to give a lecture with experiments for the course members.

In research education studies there was no course, but for licentiate's degree the student was given a research task. The professor went through the laboratory every day and was available to the students if they needed some discussion with him about their tasks, or if they needed some advice. Physics teaching proceeded in this way until 1955, when a new system was introduced.

Individual freedom was replaced by a fixed curriculum of studies. Groups of 6-8 students went through five part courses in different parts of physics during the first term. Each course was of three weeks. The first week was spent on theory and the next two on laboratory work. During the week of theory there were lectures every day for 2 – 4 hours. The week finished with a test. During laboratory weeks you worked for three days a week and these weeks were finished with a test. The second term you went through the demonstration course, the problem solving course and the course in physical technology. With this fixed curriculum the rate of study was increased and you completed “två betyg” after two terms instead of the earlier 3 –4 terms. In 1963 the system was changed again. Now there were special courses in mechanics, heat, optics (Physics I), electricity, electronics (Physics II) and atomic and particle physics (Physics III). In each course there are laboratory lessons and ordinary lectures. This structure is still in place and can also be seen in the structure of physics at upper secondary schools.

1.1.5 Women and physics in Sweden.

There were four women that studied for doctor's degrees in physics at the beginning of the twentieth (20th) century. Anna Danielsson in her paper “An impossible career? A study of Gulli Rossander, Eva von Bahr, Eva Ramstedt and Anna Beckman, Uppsala university’s first four women doctors of physics” (Danielsson 2003) has contributed to highlight and give insights into the gender structures and circumstances at the turn of the century. First Gulli Rossander (1867 – 1941) came to Uppsala university in 1887 and took her doctor’s degree in 1900 on the dissertation “The flow of gases through capillary tubes at low pressures.” With a certificate graded “Nothing beyond high commendation” she was not offered a senior lectureship or further post at the university. She was married in 1902 to senior master in physics, Henrik Petrini, and together they wrote the textbook in 1905 “Enklare fysikaliska experiment vid laborationsövningar i skolan”. They lived in Växjö, where Henrik was senior master in physics at the grammar school (läroverket) and Gulli got a position as schoolmistress at Växsjö Elementary School for Girls. She was dismissed in 1906 after an incident when she commented on the advantages of the theory of evolution. In the 1914 the couple moved to Stockholm where Gulli was a teacher in mathematics at “Whitlockska community school” and at “The New elementary School for Girls”. Gulli fought a hard battle for women’s right to vote and lived to see this realized in 1921.

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5 “Ett betyg” was the grade to reach in one semester, approx. 20 weeks studies.
6 This grade was number two from bottom in a scale of five.
1.1.6 Two centuries of physics and physics teaching

There were 400-500 schools for boys in Sweden in the first half of the nineteenth century. A pedagogical debate concerning public education was resolved by having a common elementary school with compulsory school attendance in 1842. In Sweden the population increased from 2.3 million to 5.1 million during the nineteenth century. The society was characterized by industrialization and by popular national movements. There were two parallel school systems: one established national grammar school (läroverken) and one common local authority elementary school (folkskolan); and a national inspection for the elementary schools was introduced in 1860. The debate was dominated by one liberal side more - science in the timetable and one conservative side - different schools for classical studies and studies in the natural-sciences (in Swedish reala studier). This was important as only classical studies including Latin gave entrance to the university and higher studies. But the school system had problems. Up to 75% of the students did not get any certification because of the requirement from the universities to be able to make translations from Swedish to Latin. This resulted in a school reform. In 1905 the grammar school, could be divided into one lower Latin-free part, the “realskolan” and one higher part, the “gymnasium”. Latin that has ruled the schools for two hundred years was on its way out. During this period physics itself proceeded. The function of the steam engine, force theory of heat and energy and thermodynamics started to be developed. The principal of energy was formulated by Robert Mayer (1814 – 1878), who was a medical doctor studying the processes of energy combustion in the body. James Prescott Joule (1818 – 1889) was a well-off brewer with a hobby of performing physics and chemistry experiments. His determination of the mechanical equivalent of heat had an impact on the young physicist William Thomson (1824 – 1907), who later became Lord Kelvin. Kelvin himself was an admirer of the engineer Sadi Carnot (1796 – 1832). The German physicist Rudolf Clausius (1822-1888) and Kelvin published their dissertations about heat at almost the same time.

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7 Richardsson, p.39
8 Richardsson, p.59
In 1862 it was decided to put the examinations in the national grammar schools, to be sure of a sound knowledge at start of university studies. Four technical colleges were started in 1850. Chalmers and the Royal Institute of Technology (Kungliga Tekniska högskolan) laid the foundations of technical institutes outside the universities. Upper secondary schools for girls were established in the same way at this time. From 1900 to 1970 the examinations from the grammar schools increased from 970 to 26,000 per year. The Swedish elementary compulsory school was for 6 years, with one year as continuation school. In 1936 this school became compulsory with 7 years. When the comprehensive schools were started in 1950 there were problems in the “realskolan”, the lower part of the old grammar schools. The students faced reality with drop outs and detentions. To solve this the “grundskolan”, the nine-year compulsory school was initiated in 1962 with one line (specialisation) to be preparatory to upper secondary education. This line was given up with the school reform of 1969(Lgr 69) and Sweden had finally turned from a selective school to a more comprehensive type of school, a principle that has been held to since then. In 1905 coeducational (mixed) schools were opened and in 1927 the gymnasium (allmänna läroverk) was opened to girls. In 1964 three years gymnasium was finally established together with two year vocational training schools, (but were included in the gymnasium and prolonged to three years in 1968.)

### 1.1.7 Teaching physics at the beginning of the 20th century

The slim book “Lärobok i fysik jämte öfningsuppgifter – För fruntimmerskolorna och real –lyceernas bottenklasser” written by Doctor of Philosophy JA Rosenqvist is preserved in the Royal Library. The book is dated Jyräskylä, 1896 (Rosenqvist 1896). (The University of Jyräskylä in Finland today has 16,000 students and undertakes research in physics.) The textbook has no foreword but has a table of contents with the chapters I-VI:

<table>
<thead>
<tr>
<th>Introduction</th>
<th>Substance, body. Common properties of bodies; divisibility, their states of aggregation, impenetrability, porosity. Chemical and physical phenomena</th>
</tr>
</thead>
</table>
| Chapter I Mechanics | A. Rigid bodies  
1. About the motion of rigid bodies  
2. About the state of equilibrium of rigid bodies |
|               | B. Liquid bodies |
|               | C. Gases |
| Chapter II | About light |
| Chapter III | About sound |
| Chapter IV | About heat |
| Chapter V | About magnetism and electricity  
A. Magnetism  
B. Electricity  
1. Electricity by friction  
2. About voltaic cells (elements) |
| Chapter VI | Exercises in mechanics |

Table 1.1: TOC of ”Lärobok i fysik jämte öfningsuppgifter – För fruntimmerskolorna och real –lyceernas bottenklasser” by Dr JA Rosenqvist 1896.

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9 Richardsson, p 56
In “Physics Experiments for boys in elementary schools” ("Lärjungeförsök i FYSIK för folkskolor") by Hjalmar Berg Stockholm 1917 I found(Berg 1917):

Fig. 1.5: Lärjungeförsök i fysik Hjalmar Berg 1917 (The Royal Library Stockholm) […] In several respects it has been found proper for boys to perform the experiments working two by two and that these groups at the same time occupy themselves with the same task.[…]

This way of working in physics lessons has become the rule and we now call this traditional physics teaching for laboratory work both in secondary and upper secondary schools. What arguments were behind this? According to Berg:

The results obtained by the different groups should be compared and, if appropriate, the reasons for differences should be determined. In this way the students will be stimulated to careful and precise observations. From the suggestions arising from the boys other modes of procedures could be carefully considered.

Here we recognize more characteristics from traditional teaching:

The pupils should incorporate accounts, in special notebooks, of how they executed the piece of work, and what they have seen. These notes should be reinforced by simple drawings. In this way they get a better view of the meaning of the experiment and the results that are obtained will be better remembered. The pupils could do the reports easily by reformulating the instructions given in the textbook and by answering the questions that are included there; a task that is very suitable as homework.

I would like to point out that this instructional design which is relevant to many students in the year 2004, has it roots at the turn of the century 1800 to 1900. It is as if
new memes or structures of ideas have no impact on physics teaching. As I found physics revolutionary in its fight to get into universities and schools it is a contrast to find that physics teaching is very conservative. Is it that physics teachers look up to instructions and influences from the university so much that they only administer a tradition and are waiting for new instructions to come? I think that universities lost interest in school physics long ago.

In the foreword to “Lärobok- och övningsbok i Fysik för mellanskolor och seminarier” Dr Karl F. Lindman 1917 writes:

This book would be suitable for teacher training for elementary schools that have now got more time for physics in the timetable and maybe also for industrial schools […] In aspects of content this textbook is only partly in accordance with that on compulsory laboratory sessions based instructional design that has been used since 1909 in teaching in the previously mentioned school forms. As I am convinced that it would benefit the school system in our country if such laboratory sessions were commonly used in our schools, I have given consideration to the fact that such laboratory work not has been used so far in almost any “läroverk” or “gymnasier”. I have tried to use a way that is close to this method of laboratory work but without the presupposition that it has been used earlier and thereby this will be a compromise between the laboratory method and the usual classroom teaching method.

So there was a design in the of physics teaching in “folkskolan” that was based on laboratory work. First let us take a look at how Dr Lindman introduces this new way of laboratory work in his textbook for “läroverket”:

Table of Contents: Introduction, Bodies in nature and natural phenomena, The nature of science, How to measure lengths, How to measure areas, How to measure volumes. The textbook continues with Mechanics, Sound, Heat, Light, Astronomy, Electricity and Magnetism.

In the part “To measure lengths” instruments with noniescale are introduced. One task is:

Measure the diameter of a ten-pence coin. Calculate the circumference and compare to the value you get if you make a direct try, i.e. I roll of the coin on paper.

The task is not that far from what pupils do in their textbooks today. But Folkskolans teaching had laboratory work as its characteristic and several text books show this: From 1929 Ernst Lizell-Wald Jansson’s textbook “Arbetsuppgifter för elevlaborationer i fysik i folkskolan och dess närmaste överbyggnade samt för självstudium” (Lizell 1929) tells us:

This work will serve that method of working in schools in which the pupils’ direct involvement is seen as the best way to achieve good learning results.

In this book the tasks are practical:

| What does a battery look like inside?  
Galvanic element are used frequently nowadays…[ ...]  
Accessories: A used battery, tweezers  
Performance: Gently take a battery to pieces) and observe what it consists of.  
Read in the library about salmiac and batteries. Report in the workbook. Draw a picture.  

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10The term was coined by Richard Dawkins in the book *The Selfish Gene*. Memes can represent parts of ideas or language, moral and aesthetic values and anything else that is commonly learned and passed on to others as a unit.
Other tasks are:
How do you construct an ammeter? How is a lamp made? How is a fuse made? How is an electric switch made? What is an arc lamp? Every task has a short instruction on how to start. There are also competition tasks. One is: Make a doorbell! When you read these books you recognise the today’s discussions: It is the lack of material for the lower ages and the wish to give interesting tasks to the students that will develop their understanding and competence, both in theory and practical work. As a matter of course you also find a gender perspective:

[…] using his own hands and with help from his pupils an interested teacher can, without any costs and without trouble, produce almost all material that is needed for teaching physics fundamental at folkskolan. It is in accordance with the syllabus that such work will strengthen the pupils’ interest in physics, facilitate their understanding and develop their practical ability.[…]We have chosen models that can be produced with simple materials. Even a female teacher who is unfamiliar with male handicrafts should be able to produce many of the simpler items.

The TOC shows that physics is divided into a rigid body’s motion and equilibrium, with suggestions for the construction of, for example, letter scales, spring balance, windlass, gear-wheel, balance apparatus, “yes-man”, centrifuge and loop. Fluids and gases at equilibrium and in motion, i.e. spirit level, levelling-instrument, fountain, anemometer, water and wind turbines.

Fig.1.6: To build a cooking-utensil from paper. p.68 Fysik och slöjd .HJ Nilsson & G.H. Gustafson
There are other interesting models to build: An ammeter. (See picture)

Fig.1.7: Ammeter p. 103 Fysik och slöjd. HJ Nilsson & G.H. Gustafson

Another example of what I call a miniproject which I found in ”Arbetsplaner för lärlunjeförsök i fysik för Klass V” (“Workplans for boy’s experiments”) by John Nilsson 1931. Workplans are instructions for activities in physics:

Experiment No 15: **Height (altitude) measurement by barometer.**

Lower a string from the third floor to the playground and measure the height. Take the barometric pressure in the playground and at the third floor. See how much the barometer has fallen at this height. Go down to the harbour and read the barometric pressure there. Do the same at the water tower and at Katarina hissen (A famous elevator in Stockholm) calculate the height over the sea for the elevator the third floor and for the tower.

These examples are all easy, practical and meaningful tasks given with minimal instructional text.

**1.1.8 Physics teaching in the “realskola” – and in new compulsory schools**

The structure for university physics became the content for school physics also. Stellan Löfdahl, in his doctoral thesis “Fysikämnet i svensk realskola och grundskola” (Löfdahl 1987)says about the invariance of physics text books:

My thesis seems to show the textbooks of physics as a dinosaur, sluggishly moving through the ages without care of the curriculum arrows that, in vain, bounce back or break against its scaly armour. (p.190)

Despite the curriculum instructions during the 20th century demanding that exploratory work methods and laboratory work have to be included in physics classroom work, Löfdahl cannot find that any more after the 1950s. He classifies tasks in degrees of freedom (after Schwab in Shulman&Tamir 1973).
Degrees of freedom | How task is formulated
---|---
0 | Weigh a lead cylinder on a letter balance. Decide the volume by putting it into a measuring cylinder half filled with water. Read how much the surface of water rises; this gives the volume of the lead cylinder. From this determine the value of density of lead. The value in tables is 11.3 g/cm³.
1 | Weigh a lead cylinder on a letter balance. Decide the volume by putting it into a measuring cylinder half filled with water. Read how much the surface of water rises; this gives the volume of the lead cylinder. Determine from this the value of density of lead.
2 | Determine the density of lead.
3 | Investigate the properties of lead.

Table 1.2: How physics tasks determine how to work at school. p65 Löfdahl

The results show how this strong guidance increases at its top in LGr 69’s textbooks. Here 97% of the instructions rules in detail how laboratory works should be done.

<table>
<thead>
<tr>
<th>Degree of freedom</th>
<th>1905</th>
<th>1928</th>
<th>1933</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>7</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>1</td>
<td>82</td>
<td>64</td>
<td>72</td>
</tr>
<tr>
<td>2</td>
<td>9</td>
<td>33</td>
<td>16</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

Fig. 1.8: Percentage of parts having different degrees of freedom in textbooks exercises. (Re-written). (In Löfdahl, 1987, p. 166)

How then is the situation in upper secondary schools and how did they develop after the upper secondary school certificate discontinued? The tradition of theory lessons followed by laboratory sessions is still there and can be seen in textbooks from the old gymnasium and from the new gymnasium. The gymnasiums are closely connected to the traditions of university physics since the 17th century.
In the latest curriculum (Lpo 94) for upper secondary school physics the content is as it has been earlier, but some aspects of science in society are included:

*Physics A* treats, energy and heat, light, electricity and the internal properties of materials. An orientation of the science history and the problems with energy supply.[…]

*Physics B* treats the areas of mechanics, electromagnetism, mechanic and electromagnetic waves and atom and particle physics. The course also gives an orientation of the development of the universe. The course includes a special area chosen from teachers’ and students’ interests.[…]

This means that nothing has been taken away but more material is included. And how is the instructional setting in schools today? Do the teachers follow the textbook instructions or do they sort out interesting parts from the content? A classical work that became a help and inspiration to teachers was the small books “Experimentella problem i fysik” Del 1-3 (Norlind, Grönkvist, Hess Westling) published in 1987(Norlind 1987).

In the forward the authors say:

One can find plenty of exercises in physics as they are collected in the textbooks. But these collections of exercises introduce a new approach, namely experimental problems.[…] We have collected them from our own teaching over ten years. In aspects of learning they are interesting in many ways. They give an opportunity to experience a concreteness that the theoretical exercises do not give. They give training in some practical and experimental abilities and they give connections to everyday life and technology.

This example shows how teachers impact and create their own physics course in spite of the traditional textbooks. The British project “Advancing Physics” was built on the teachers’ own material collected over several years to create a physics course at A-level, with a wide scope and variety. The variety in this huge collection of material makes it unique and gives an opportunity for teachers to select from all these tests, laboratory work and demonstrations. This gives a potential for ownership to both teachers and learners. Going for developing teaching sequences to guarantee that a physics concept is taught in a correct way instead is a dangerous way to go. Of course teacher training has to give new teachers examples of how to start to teach, but ownership for experienced teachers is very important.

### 1.1.9 Learning in the 21st century

Science and technology are no longer found to represent security in a society where everyone has a guarantee of earning their living. Science became the carrier of a negative attitude to life and of a tradition of military industry and environmental pollution. This gave rise to a distrust of the scientific world picture in contrast with young people’s development of technology with computer games, mobile phones and electric music. What is learning today? Have young people created such demand to participate in different discourses as today? This is a sign of learning!

To be able to wander between discourses in which you are a valid partner in the conversation demands knowledge, not only knowledge of facts but also other skills, for example maturity, general knowledge, knowledge of languages, knowledge of cultural differences and similarities, to have a sound judgement …

A young person today can be expected to participate in the following discourses. She is going to understand and be able to participate in conversations concerning the world peace, the earth’s energy balance, the meaning of life and the quality of cellular telephones and to make risk analyses regarding nuclear power and electromagnetic fields. To her employer she has to stand out as capable; not only professionally, but
also to be a good partner so that in the discourses of working life she can be effective and successful. The examples can be multiplied.

Jan Schoultz wrote:

To learn natural science implies to be socialised into a discursive tradition with special concepts and rules that have been developed over a long period. Learning in this perspective can be regarded as being that the person increases her familiarity with the meaning of the concepts and their fields of application. It is therefore important that the student in conversation and interaction with a more experienced person gets the possibility to concretise and apply the concepts. A conversation is exactly such a situation where you learn and where knowledge is constantly recontextualised and formulated. (Schoultz 2002)

Hence in time the concept of learning will describe a person who can be part of meaningful conversation with different kinds of people and share their thoughts and search for knowledge and solutions to problems.

1.1.10 An ambivalent approach to technology

The third epoch according to Mitcham’s *Romantic Discomfort*, is the last century’s ambivalent approach to technology. The lust for the creative production is counteracted by the tendency to destroy something at the same time. Technology gives the individual freedom but counteracts social unity. Fantasy and vision are more important than technological competence. Artefacts can emphasize the sublime and enhance the process of life.

Mitcham considers that philosophy has made progress with the philosophers who, at the same time, took an active part in society. He exemplifies with Socrates and Plato as politicians, Aristotle as a biologist and Augustin as a bishop. Descartes and Leibnitz as physicists and mathematicians and also Rousseau and Marx as revolutionary politicians in their time. With this as a background he wants to place the philosophy of technology as a part of STS (Science Technology and Society). This gives philosophy an active part in culture he has earlier seen fruitful. An increased awareness of STS emerged in the sixties due to environmental problems, nuclear weapons, automation, energy crises etc. Two publications came to affect the development in 1962; Rachel Carson’s “Silent Spring”, and Thomas S. Kuhn’s “The Structure of Scientific Revolutions”. Different groups in society reacted in two ways. Either you realised that the solution to the problems lies in getting more knowledge about technology and natural science and the use of refined techniques, or you limited use of technology and emphasises the risks.

1.1.11 Why ownership, motivation and competence?

I searched the background to my own driving force to investigate student ownership, motivation and competence. I found as opportunities for learning curiosity to solve a practical problem or a deep interest in a problem area. There must be an environment with response and reaction towards your results. Students have to learn basic skills in school. But the exponential growth of discoveries in science makes it impossible to use physics teaching to retell all that has happened. The teaching tradition in gymnasium that came with the university teachers at gymnasium in the 19th and 20th centuries has made physics problematic to students. Physics has to focus on giving students knowledge and ability to develop an attitude towards scientific questions in a highly technological society, towards environmental pollution, genetic engineering, space research etc. Students need to think critically about how science can be used on planet earth. Students have to get possibilities to learn basic physics as a scientific subject but only as an introduction into university
physics. But we cannot continue to imitate university physics from the 19th century to get students interested in physics. Those who have influence in the machinery of power and control of curriculum and syllabus have to realise that the time has come for the gymnasiums to get rid of their dependence on the universities teaching traditions. The teaching tradition that put the practical use high and found understanding to come from experimental problem solving is maybe still revolutionary if it can be reused in a context that is relevant to young people of today. This work will serve that method of working in schools where the pupils’ self-involvement is seen as the best way to reach good learning results.

1.2 Background to the study and me as researcher
I have experience as a physics teacher in Swedish upper secondary school since 1982. I have taught physics in teacher education at introductory university physics level since 1998, and from 2002 I am a doctoral student in the Swedish National Graduate School for Science and Technology Education, FONTD. The tradition to teach physics was earlier to bring about knowledge through telling theory and by showing physics demonstrations. The purpose with teaching was to solve standard problems and to make definitions and connections between physics concepts clear. The students did laboratory work in half class often in small groups two by two. The laboratory work was often of the kind of verifying a physics law, and a lot of attention was given to the formal outcome of the investigations made. The report and the error estimations were the important parts of the investigations. The lessons were about 2-3 hours a week, and laboratory work sessions 1-2 hours every second week. The same teacher taught in physics as well as in mathematics and it was common to prepare physics in mathematic lessons too. The Physics course was almost always defined as the textbooks authors’ versions of the syllabus, and the guidelines to lab work given in textbooks dominated the course. With the new syllabus of 1994 there were possibilities to a more open-minded view on physics teaching, and in many schools the learning environment started to change. Influences from problem based learning (PBL) made teachers to introduce thematic projects cross the subjects of physics science, science and social science. The school organization in courses of subjects made these influences to be done only with a lot of effort from eager teachers. The developments of new teaching forms were held back by the organization of the schedule. A long tradition of building up equipment for demonstration was in function in the schools. With two tests every semester, the traditional way of teaching physics was very rational to get high scores in tests and to reach the course goals for both teacher and students. As the society changed and the student with it, physics became a subject that was held to be boring, difficult and uninteresting, even meaningless to many students. The main reason to have physics was because it was needed for well paid jobs as doctors, veterinary surgeon and university engineers, but the subject could not well enough relate to the student her/himself.
In what way can the student attitudes towards physics then change? How can research then contribute to better physics teaching? Is there something that can make students see the wide area of questions that physics includes, philosophical, technical and with the knowledge of how nature functions?
When I started to use physics demonstration equipment not for demonstration but for laboratory stations during my physics lessons, I experienced a very positive feedback from students. They liked the activity and the opportunity to talk physics with me and with their peers in a direct and easy way. This was for me the start to work with
physics in miniprojects. I found it important for students to get more ownership to their studies, and to change the learning environment to be more flexible to student needs and gifts. To focus the gender question of physics, collaborative learning also could be a way that strengthen the female entry into science. Benckert expresses this with the observation that even if physics for many persons is the objective science itself, physics has a gender problem due to the fact that a great majority of physicists are men. Problem based learning and small group work is a way to give girls interest in physics education. Benckert gives her vision of science education:

(In my translation to English)

My vision is a physics education that is less “clean”, where the historical development of physics, applications and connections to the contemporary society are integrated into and discussed in the education, and where “the masculine cloud”, there is in physics, is analysed. (Benckert 1997)

I share her vision. Some questions have become important to me and became a background to this research project: Can the student lead his/her own learning process in a way that is effective and gives pleasure, by using personal qualifications to solve a laboratory problem? Can tasks be given as a complementary moment in physics in order to give students freedom to begin in his/her own level of knowledge in aspect of facts and understanding in the content area? Can use of miniprojects (MP) and context rich problems (CRP) give possibilities to introduce problems and tasks with a more holistic approach than that of pure physics, in order to increase the students’ possibilities to recognise physics in different contexts? Could environmental physics included in physics increase interest and motivation by giving a more holistic perspective? These thoughts give the background to the research questions that are formulated in the thesis.

1.2.1 To learn and teach.

My starting point is the teacher as participant and sharer of the learning environment. For me some step stones are obvious:

- The learning process always continues all the time.
- We continuously develop different parts of our consciousness but at different speed.
- Learning depends on context and situation.
- We are biological creatures that give us special limitations and conditions.

I have of course developed these believes during influences of the pedagogical debate I have lived in, but also because of my relations to family, friends and to my dogs and horses. Do others look at learning in the same way as I do?


I believe that one of the greatest difficulties in the present teaching of science is that the material is presented in purely objective form, or is treated as a new peculiar kind of experience which the child can add to that which he has already had. In reality, science is of value because it gives the ability to interpret and control the experience already had. It should be introduced, not as so much new subject-matter, but as showing the factors already involved in previous experience and as furnishing tools by which that experience can be more easily and effectively regulated.

...I believe finally, that education must be conceived as a continuing reconstruction of experience: that the process and the goal of education are one and the same thing.

A hundred years later writes Nancy G. Nagel:

Our knowledge base is expanding in such a rapid rate that traditional curriculum and teaching approaches no longer are effective....
Children need help to bridge the worlds of school to the larger community in which they live. (Nagel 1996)

There is a longing inside us to be able to act and make things become real by what we learn: to build, write, play music instruments... There is a tendency to long for perfection or entirety. We want to be the one who can do something, not only the one who knows about something. We want to learn the specific not the general, but the students are preferable offered the general. I will come back to how I relate this to physic teaching in secondary high school. Brickhouse writes in "A Feminist Perspective of Learning" (Brickhouse 2001)

Learning is happening all the time - whenever a person engages in activity in the world. Learning is unavoidable. It is what is required in the process of becoming a person. Learning is not merely a matter of acquiring knowledge, it is matter of deciding what kind of person you are and want to be and engaging in those activities that make one a part of the relevant communities.

It is not easy to distinguish one act of learning from another. When students work in small groups a lot happens, some related to the students tasks, very much concerning the social environment in the student group. Many students learn a lot, but not always what the teacher intended. The teacher who gets involved in the students work learns a lot too, and that is one of the forces or basic instincts to stay in the profession, the possibility to learn more. How could one catch in what way a lot of people, in the same time, create their personal knowledge, interacting to each other in different levels? And how to relate to knowledge in the subject of physics?

Lave & Wenger (Lave 1990) give perspective of the situated learning as knowledge that needs to be presented in an authentic context, i.e., settings and applications that would normally involve that knowledge. They also find that learning requires social interaction and collaboration. I find it possible to learn physics in school, and this because its connection to questions of life, matter, universe, the made-world and to information is relevant and of interest to everyone. But it also becomes obvious to me that physics and science education have to include physics teaching in three areas:

- physics science and our role in university– is science relevant to me in any aspect – to let the student develop his/her identity by talking the big questions in an ontological aspect
- physics science and technology in society – a discussion with a perspective on history and future about applications and responsibility, research ethics and research openness, general knowledge as scientific citizens, (Gibbons 1994)
- physics science as training to be a physicist; learning the natural laws of physics

1.2.2 To be a researcher.

Research is defined as a systematically and methodological search for new knowledge, and new ideas. This thesis follow a social science research approach and from Alvesson & Sköldberg (2000) four interesting topics give a frame for the reflective areas to which the researcher should be engaged:

1 Systematic and techniques in research procedures
2 Clarification of the primacy of interpretation.
3 Awareness of the political-ideological character of research.
4 Reflection in relation to the problem of representation and authority. (Alvesson 2000)
Systematic and techniques in the research procedures are connected to validity and reliability aspects. Here is also the quality of the supervision of importance, as the thesis is one step in the research education.

The primacy of interpretation given to the researcher is a responsibility to handle by giving details of the researcher’s background, intentions and pre-understanding. This is also of importance for the awareness of the political-ideological character of research.

Here I can see my loyalty to the students as both a resource and a burden. At least I am aware of the respect I feel towards students working hard in problematic learning environments, and a passion to help them improve their possibilities to learn. I also find myself doubtful whether the state are serious in their will to increase the student body studying physics and natural science in schools, as all signs I see tell me the opposite, i.e. decreased demands and time for the science of physics in both university and schools time schedule.

Concerning representation and authority I find it close to the view of learning itself. Learning for me is to draw near to phenomena, that I never will understand totally, but still be able to get closer by my increasing experience. Other people will do the same, and this our variation of perception will build an image of the phenomena. The result will be that our interpretations will contribute as different iterations contribute to the image of the Julia sets, as when Gaston Julia studied the iteration of polynomials and rational functions in the early twentieth century.

With this text people will interact in a way their experience lead them to, and I am aware of that this will maybe not follow the intentions that I may have.

1.2.3 Choice of instructional settings
Science education literature contains many reports stressing the importance of making physics meaningful to students by studying questions of interest for the community and for the students themselves. To support this, different instruction settings have been developed, for example problem-based learning, project-based learning, case-methodology, and inquiry-based instruction. (van Heuvelen 1993; Nagel 1996; Blumenfeld 1997; Krajcik 1998; Lewis 2002). In order to study how motivation, ownership and competence are related when students study physics in small group work with miniprojects (MP) and context rich problems (CRP), we have designed two investigations. One with fourteen student teachers in physics has been made during the autumn 2002 at a Science Teacher Education. They studied their second physics course, electrodynamics, when they for two weeks worked with miniprojects in physics. The other study has been made in the spring 2003 in a Swedish upper secondary school.

Miniproject is an instructional approach. Students work for a limited amount of time on their own questions, with their own methods, and coming to their own results. They often work on experimental problems. The educational purpose of the miniprojects is to allow students to study physics in a way they themselves choose and have deep impact on. They have use of their earlier experiences, and can still cooperate with peers in solving problems. They can try to grasp totally new topics or get deeper into something well known. Used as a complement to ordinary teaching, miniproject is a way to give teachers possibility to implement and use several instructional methods. CRP is another instructional approach influenced from problem based learning (PBL).

From these investigations this licentiate thesis reports six cases in a mutual case study to high-light the relationship between ownership, motivation and competence.
One purpose of the thesis is to elucidate and make a sharper definition to the concept ownership. By ownership we mean the learners possibility to have impact on the learning situation. We find that ownership is crucial for motivation and development of competence. By competence we mean to be able to “talk physics” (Lemke 1990), be able to illustrate physics in practice, to have a conceptual understanding and problem solving abilities, have holistic perspectives in aspect of nature and in aspect of technical applications.

This will be explained in the next chapters.

1.3 Purpose of the study and of the thesis

The study will highlight different aspects of student ownership to their learning when mini projects (MP) and context rich problems (CRP) are used as instructional settings included in a traditional teacher centred physics course at upper secondary school level or in introductory physics courses at teacher education in university. These instructional settings are expected to give students possibilities to strengthen their holistic understanding and more motivation through more ownership. In this study, students’ interactions in group discussions and activities during work are explored and analysed as case studies. Case studies build on theoretical concepts like motivation and ownership that are used to generalise interpretations into a theory. Case story is to retell what happened in the case and give interpretations. I try in the thesis to reach case studies. Comparison between group members in the same MP group, between different MP groups, between MP group and CRP group will be given in aspects of their competence and interest before start, their communication, motivation and activity during work and the quality of outcome in presentation and results. The concept student ownership of learning will be defined and an instrument to analyse ownership will be developed. The case studies are seen as an exploratory study that will generate hypotheses for a second study.

In the thesis I have as purpose to:

- Define the concept student ownership of learning, and give examples.
- Explore how motivation and ownership are to be seen in small group work in physics with MP and CRP.
- Develop hypotheses concerning the relationship between ownership, motivation and development of some aspects of competence.
- Explore how aspects of communication in the group are related to ownership and motivation.

To address the general purposes of the study the following actions were adopted:

1. A pilot study analysing the choice of MP that were graded in different degrees of freedom and different degrees of holistic perspective. The student population in one of the courses consisted of students with a non-science background attending a bridging course in physics. Students in the other course where in their final year of a bachelors program in computer science, electric engineering or environmental engineering, studying together in an environmental physics course. Both groups have been working with miniprojects in the content area of electromagnetic radiation (spring 2002).
2. A study analysing the choice of MP and the ownership, motivation and communication during work process with teacher students having MP as a twenty percentage part of a physics course in “electromagnetism for teachers”. (winter 2002)

3. A study of ownership, motivation and communication with upper secondary school students in their second physics course having MP and CRP during four weeks included into their traditional instruction. (spring 2003)

1.4 Delimitations
The teachers striving to increase student possibilities to ownership often find that their own ownership is limited due to schedule, school traditions and a lot of practical realities that become obstacles to change the instructional strategy normally used. MP and CRP are possibilities to improve ownership to students in aspects of the physics lesson design, and could be seen in this way. Of course there is a lot of other variations of instructional strategies influenced by problem-based learning (PBL), and a teacher is capable of doing her/his own variation that will fit her/him and her/his class. Hopefully researchers with a theoretical interest to see student influence as a question of power will investigate student ownership to learning (SOL) as a question of power, maybe also connected to the deeper understanding of the expectations from society in how public understanding of science will take form. (As I find science to have such a revolutionary history in science, maybe there are interests to handle even school science in a way that it render harmless. And what could be better than to stay in a tradition of teaching that is the same since 150 years, despite the rhetoric that we need more science schooled citizens.)
The aim of this study anyhow will contribute to the understanding of how one can analyse students at work with a task during process, and get a picture of their ownership and motivation and development of some aspects of competence in physics. No more or less. Due to the methods this study we do not analyse the individuals technological skills and instrumental mastering, even if this is seen as one component in the competence in physics. As the main question is to evaluate the phenomena student ownership of learning, and as this phenomenon appeared to me in the use of miniprojects in physics teaching, I do not find it necessary to position myself into a specific scientific research perspective, as the use of methods does not demand any such attitude. I focus on my research question, and develop SOL from the physics teacher’s perspective.
Chapter 2  Theoretical background

2.1  Miniprojects (MP) and Context Rich Problems (CRP)

2.1.1 Miniproject (MP)

The MP is an experimental problem chosen in order to obtain clarity of the connection of physics concepts included in the specific context. The context is preferably related to a real-world problem. The small groups’ works include 1 – 4 students. After choosing and preparing for the project the group will have one ordinary lab session to do the practical part of the project. Later they will make a report of the investigation, preferably as a PowerPoint presentation of 10-15 minutes.

Holistic perspective in the miniproject.

To make physics meaningful to students it is important to begin to study questions of interest to the community and to the students themselves, as reported by Nagel (Nagel 1996). But what makes a problem holistic and meaningful in this sense? There are several aspects to consider. A technical problem can be meaningful to one person but not to another. An environmental physics problem can be really broad and holistic to some people.

Ownership of the MP

Students’ experience and their ability can be expected to guide them and give them pleasure in deciding their own way of learning. Ownership of the miniproject will become an opportunity to use what they have learned before in other learning environments and to complement this with a new type of knowledge that other group members can inspire them with.

What is the purpose of using MP?

- To give the student the possibility to manage her/his own learning process.
- To take advantage of the students’ personal abilities to solve a problem
- To give the student freedom to approach a problem at own level of ability.
- To give the student a chance to accomplish a task without being compared to others, to solve a unique problem.
- To give the student the possibility to choose intuitively a task that offers development of understanding.
- To give the teacher a possibility to introduce questions in order to give a more holistic understanding and meaningfulness to students.

Fig.2.1: Implementing the MPs

1 Content Pilot study Experience
2 Unique Question
3 Planning of performance, result level presentation
4 Lab work Data collection Results
6 The final presentation and product
5 Reflections
2.1.2 Context Rich Problems (CRP)
A context rich problem is a physics problem hided in a story, given to a small group of three selected students. The CRP is by that different from an ordinary text book problem. The design of the problem encourages students to use an organized and logical problem solving strategy instead of mere formula driven random search strategy. They are designed to force the students to consider concepts in the context of real objects in the real world. As defined by the University of Minnesota, these problems have several characteristics (Heller P. 1992):

- The problem needs to be challenging enough so that a single student cannot solve it, but not so challenging that a group cannot solve it.
- The problem should be structured so that the group can make decisions on how to proceed with the problem.
- All the required information may not be given, for example the weight of a person or a distance that may be easily estimated. Furthermore, extra information may be given that is not required to solve the problem.
- The problem should be relevant to the lives of the students.
- The problem should not depend on students knowing a trick nor should they be mathematically tedious.

The Context Rich problems have these features:
- Each problem is a short story in which the major character is the student and they use the personal pronoun.
- It includes plausible motivation or reason for the students to calculate something.
- The objects in the problems are real or can be imagined.
- Typically no pictures or diagrams are given. Students need to actively visualise the situation using their own experience.
- The problem cannot be solved in one step by plugging numbers into a formula.

In further, more difficult context rich problems may include these features:
- The unknown variable may not be explicitly specified in the problem statement. For example, a question after a description of a situation the conclusion may be something like "Will the design work?" or "Do you believe the boy’s story?" These types of statements encourage students to practice reducing a problem to something they can calculate, but actively forces thinking as to what to calculate.
- Assumptions may need to be made to solve the problem. For example, the students may need to assume a reasonable value for a person’s mass or they may need to assume an idealisation to make the problem solvable.
- A problem may require the use of more than one fundamental principal if it is to be solved. For example, Newton’s Laws and conservation of energy.
These characteristics reinforce the idea that problem solving is a decision making process. It emphasises the need for students to use their conceptual understanding of ideas to analyse the problem before introducing equations. To invent a context rich problem one can start with a textbook exercise or problem and then modify it. Some examples:

- Always start with the word "You". This personalises and motivates the problem for the students.
- If necessary determine a context and decide on a motivation. Why would anybody want to calculate something in this context? Optional – write the problem like a short story.
- Decide on how many difficulty characteristics you want to include
  a) extra information
  b) leaving out common knowledge, for example the exoneration due to gravity
  c) writing the problem so that the target variable is not explicitly stated
  d) thinking of information so that two distinct approaches are needed for example forces and kinematics.
- Check the problem to make sure it is solvable, the physics is straightforward and the mathematics is reasonable.

### 2.2 Basic concepts

#### 2.2.1 Motivation

The concept of motivation comes from the Latin verb *movere*, to move. The word is the same and is spelled the same in English, German and Swedish. The meaning of the word is broad but in research it is used to describe the energy put in the process of doing something and the effort to get the job done.

Research into motivation has a long history and there are several motivation-theories. During the 20th century motivation theories have developed from motivation seen as inner forces, as instinct or will and volition. McDougall (1926) understood instincts as the basic reason for actions and with one component being the awareness to satisfy the instinct (the Cognitive component), another being denoting the emotions aroused by the instinct (the Affective component) and the third component being the striving to achieve the goal (the Cognitive component). He believed that students’ instincts could be triggered by school activities. The problem with his instinct theory comes with learning and to specify where instinct ends and learning starts.

(Freud 1966) described motivation as reflecting psychical energy. Freud saw the energy flow inside a person as driven by inner forces and needs. His theories are now seen as difficult to verify empirically but others have described motivation theories based on driving forces.

Conditioning theories studied behaviour and stressed the stimuli and responses as the mechanism responsible for behavioural change. Three different theories based on this principle were connectionism by Thorndike (1913), classical conditioning by Pavlov (1927) and operant conditioning by Skinner (1953). These theories had impact on teaching during the first half of the 20th century and were stepping-stones to the educational technology that influenced western countries.
The achievement theory (Murray 1938) started to see motivation as the optimal performance of a task. Early the *expectancy construct* was seen as a mediator of achievement behaviour. This developed into three research traditions: the expectancy-value theory, self-perceptions of competence research and self-efficacy theory. Several achievement theories (McClelland, Atkinson, Horner) and mastery and growth theories (Maslow, Pamela Griffith) were developed as well. In McClelland’s motivation theory one has three components to take into consideration; high performance, social power and social interaction. Griffith (1987) describes a hierarchy of needs based on Maslow (1954) with personal, social and intellectual needs. Here the attitude is to strengthen also the weaker individual’s personal development not just the leaders.

In this way, goal theories developed from basic biological needs to also include social needs. The dominant goal theory nowadays is the *Goal Orientation Theory*. It states that students have two general goal orientations that they can adopt towards academic work. The first is a *mastery orientation* that sets learning as the primary goal. The second is a *performance orientation* that primarily wants to demonstrate ability, take grades or rewards or shows that one is better than other students. Studies linked to this theory have shown that mastery goal orientation leads to positive effects and interests and better performance. (Pintrich P. R. 1996)

Social cognitive theory says that behaviour represents an interaction of the individual with the environment. Bandura (1963, 1993), sees motivation as “a goal-directed behaviour instigated and sustained by expectations concerning anticipated outcomes of actions and self efficacy for performing these actions.” (Pintrich P. R. 1996) Learning is then motivation to reach skills and strategies more then to perform a task.

Social Cognition Theory has been used in the study of *self-regulation*. Early explanations of human behaviour were based on basic biological needs such as hunger and thirst and other needs and on extrinsic rewards or punishments but one realized later that people also act for other reasons. These actions gave people positive feelings of interest, joy and satisfaction and did not necessarily have a specific outcome. This is called *intrinsic motivation*. Intrinsic motivation is motivation to engage in an activity for its own sake. (Pintrich P. R. 1996) It is contextual and varies in time and with occasions. Emergent motivation is a perspective on intrinsic motivation that comes from Csikszentmihalyi. He calls “the holistic sensation” that people feel when they are totally involved in a task, “flow”. A person can reach “flow” working with a task that achieves equilibrium between the amount of challenge in the activities and the person’s ability to perform the task.

What do we mean then by studying motivation?

Pintrich and Schunk identify motivation as “the process whereby goal-directed activity is instigated and sustained”. (Pintrich 1996). They follow a research tradition within achievement goal models theory (Ames, Archer & Scevak, Wentzel) (Elliot 2001), that define intrinsic motivation in terms of focus on the task and a goal of mastery, learning and understanding, and not in reference to basic needs as to be self-determining or autonomous, e.g. (Deci 1991). The difference between mastery goals and performance goal are in later work described as mastery oriented goals (focus on developing knowledge, skill and competence) and performance oriented goals (towards doing better than others, demonstrating ability to one’s teacher or peers, getting rewards). Even if researchers disagree about the background reasons to motivation, one commonly uses the same motivation indicators:
A Choice of task: Selection of a task under free-choice conditions indicates motivation to perform the task.

B Effort: High effort - especially on difficult material is indicative of motivation.

C Persistence: Working for a long time – especially when one encounters obstacles is associated with higher motivation.

D Achievement: Choice, effort and persistence raise task achievement.

Methods found to access motivation in research are: Direct observations, Rating by others or Self-reports (questionnaires, interviews, stimulated recall, think-aloud, dialogues).

Extrinsic and intrinsic motivation
The distinction between intrinsic/extrinsic motivations are discussed in the same approach as mastery/ performance goals in achievement goal theory, with that I mean as contradictions or to be in opposition each other. During the 1970s Deci started to question the relation between extrinsic and intrinsic motivation and started thereby a debate that is still going on. In the book “The Hidden Costs of Rewards” edited by Lepper and Greene (1978), a large number of studies were documented explaining that using an extrinsic reward to motivate someone to do something that the person would have done anyway could have detrimental effects on the quality and creativity of the person’s performance and on the person’s subsequent motivation to perform the activity once the extrinsic reward was received” (Sansone 2000).

The connection between this debate and self-determination theory will be high-lighted further.

2.2.2 Ownership of learning
Marina Milner – Bolotin (Milner-Bolotin 2001) made her dissertation “The Effects of Topic Choice in Project-based Instruction on Undergraduate Physical Science Students’ Interest, Ownership and Motivation” in 2001. Her study focused on student autonomy in choosing project topic, their motivational orientation, student ownership of the project and their interest in the project. She used the achievement goal orientation as a theoretical framework for her study, and evaluated mastery and performance goal orientation with the achievement goal orientation questionnaire. She developed a questionnaire to evaluate ownership called ownership measurement questionnaire. The questionnaires were analysed quantitatively with multivariate analyses, and complemented by qualitative analyses as well.

She found that student autonomy in the project choice did not make a significant impact on their motivational orientation, but their initial interest in the project topic did.

She found this to be a consequence of the students’ ownership to the project, and this was found to lead to improved mastery goal orientation, which in turn may result in improved science learning.

She defines learner ownership operationally as:
A learner has a high degree of ownership of the project if the learner
a) finds personal value in pursuing the project: understands how this knowledge might be useful, is able to connect the recently acquired knowledge to his or her prior knowledge;

b) feels in control of the learning process he or she is involved in via making decisions, and being a proactive, rather than reactive learner;

c) takes responsibility for the learning process as well as the result of the project.”

Fig 2.2: Learner ownership as an interactional effect between three components of learning process: taking responsibility, feeling in control, and finding personal value.
(Milner-Bolotin 2001, p 42)
Milner-Bolotin defines learner ownership related to a student activity: finding, feeling and taking in the project work situation. Milner-Bolotin operationalises ownership from her Ownership Measurement Questionnaire OMQ. The result is based on the students’ answers of how they have experienced their project work on an individual level. The work process itself was explored by student portfolios, their electronic communication with the instructor and by the researcher’s observations, but this is not reported frequently.
In a earlier dissertation “Fostering student ownership for learning in a learner centred instructional environment” Savery (1996) present “the model for ownership of learning”, that draws from the psychologist McCombs (1993,1995) clusters of psychological principles. In the four categories 1) metacognitive and cognitive factors, 2) affective factors 3) personal and social factors and 4) individual differences he define behaviour indicators to study.
His aim is to use an instructional design based on eight constructivist principles, to promote learner ownership, to foster situated learning, and to encourage collaborative problem solving. He uses the four categories of factors and develops behaviour indicators to understand ownership. In this broad approach he finally uses 16 checkpoints of behaviour indicators from the ownership model. As the concept ownership not is defined explicit, his behaviour checkpoints give a picture of how he understands the ownership of learning.
First, he describes metacognitive and cognitive factors. These are “Sets meaningful goals”, “Self-monitoring”, “Self-directed” and “Construct knowledge”.

By affective factors he means “Motivation balance extrinsic/intrinsic”, “Control of learning environment” and “Engages with learning tasks”.

Also Social/Personal factors are included: “Collaborative teamwork- peer tutors-help”, “Leadership”, “Effective communication”, “Self-esteem” and “Maturity”.

Finally Individual Differences concerning the student “ability”, “attitude towards learning” and “attitude towards assessment” are characterised.

Savery stresses the educational importance to understand how ownership is demonstrated in a variety of instructional settings, as ownership for learning is characteristic of successful learners. Within this study (Savery 1998) he calls for further refinement of the behavioural indicators and the development of more detailed student questionnaires, to more accurately determine the level of ownership of students presenting situation specific behaviours.

From these two researchers results I find a need to sharpen the definition of ownership into a more narrow distinction, close to observations of what really takes place during work in the project groups and in group work. The communication aspects including how negotiations take place during choice of task, during work process and finally how result and presentation are related to the earlier stages of the group work are important to show, if the purpose is to explore how motivation and ownership are related. As achievement goal theory is theoretical framework, these studies naturally focus on outcomes regarding ownership and motivation in a special instruction setting. I like to focus more on the process itself; what aspects define motivation and ownership as we see it in the process, and how do students handle these negotiations during group work. What are the attributes to ownership? How is the group situation described in terms of motivation and ownership?

Fig : 2.3 A Model of Student Ownership for Learning (Savery 1996)
2.2.3 Self-determination theory (SDT)
Edward L. Deci presents Self-determination theory (Deci & Ryan 1991) as a help in education to promote student interest in learning and to help students to find confidence in their own capacities and attributes. Studies guided by self-determination theory indicate that “the highest quality of conceptual learning seems to occur under the same motivational conditions that promote personal growth and adjustment”. The core in self-determination theory is to distinguish between self-determined and controlled types of intentional regulation. See figure.
Motivated actions are self-determined to the extent that they are engaged in wholly volitionally and endorsed by one’s sense of self, whereas actions are controlled if they are compelled by some interpersonal or intra psychic force. When a behaviour is self-determined the regulatory process is choice, but when it is controlled, the regulatory process is compliance or in some cases defiance. (Deci 1991)
Compared to achievement goal theory (Ames, Archer & Scevak, Wentzel, Bandura, Dweck) (Dweck 1986) that see motivation with focus on goal our outcomes that lead to the desired goals, the self-determination theory focus also on the process and the energisation in the process. SDT focus on three basic human needs. The need for competence (Harter 1978), relatedness (Reis 1994) and autonomy (self-determination). Motivation, performance and development will be maximized within social contexts that provide people the opportunity to satisfy their basic psychological needs for competence, relatedness, and autonomy.

![Figure 1](image_url)

**Figure 1**
The Self-Determination Continuum Showing Types of Motivation With Their Regulatory Styles, Loci of Causality, and Corresponding Processes

We like our students in school to be curious, vital and self-motivated. When students are at their best they are eager to learn, happy and apply their talents in a sensible way. But we often find them apathetic, alienated and irresponsible. Research on the conditions that foster or undermine motivation and personal growth has practical significance as it can help to design teaching for students to improve their development, performance and well-being.
Autonomy-supportive versus controlling teachers
(Reeve, Bolt and Cai) (Reeve 1999) report how teachers vary in their interpersonal styles they use to motivate students to learn. They call these styles autonomy-supportive versus controlling. Students in class-rooms with autonomy-supportive teachers do better in aspects of perceived academic competence; they show enhanced creativity, greater conceptual understanding and more positively emotionality. SDT explains this with that autonomy supportive teachers enable a self-determination motivation in students that facilitates these benefits. There are tools developed to decide a person’s tendency to be autonomy-supportive versus controlling. As an example this is a question from (PIS) “The problem in schools” questionnaire:

Question F: Your child has been getting average grades, and you’d like to see her improve. A useful approach might be to:

1. Encourage her to talk about her report card and what it means for her
2. Go over report card with her; point out where she stands in class
3. Stress that she should do better; she’ll never get into colleges with grades like these.
4. Offer her a dollar for every A and 50 cents for every B on future report cards.

According to SDT answer 1 is highly autonomy-Supportive answer 2 is moderately autonomy-supportive answer 3 is moderately controlling and answer 4 is highly controlling. Deci and Schwartz (1986) find teachers motivating styles stable over the academic year.
2.2.4 Students’ ownership of learning as an aspect of student influence.

The interim report SOU\textsuperscript{11}1996:22 “Inflytande på riktigt – om elevers inflytande, delaktighet och ansvar” establishes three reasons why students should have influence:

- because it is a human right
- because the school’s task is to foster democratic citizens
- because participation is a condition or prerequisite of learning

((Skolkommittén 1996), p.21)

The committee points out that freedom of choice from the offer of different courses in the syllabus, contrasts with integration and cooperation between subjects. There are risks that the tradition of a strong timetable is one of the obstacles to student influence. I find the apparent efficiency of organisation of traditional physics courses to be an obstacle to student influence and learning. The lack of a reflective attitude towards the subject itself is the problem. Having respect for the students I find it necessary to give them some possibility to reflect and go into discussions and activities chosen by themselves in order to create meaningful relations between physics as a subject in school and the reality in the world around. This thesis focuses on the third statement - student influence, as participation, is a condition or prerequisite of learning.

In the doctoral thesis of Selberg (Selberg 1999) she studies student influence on their learning as well. She divides the groups having “small experience of influence”, “quite large experience of influence” and “large experience of influence” by asking them how often the students decide for themselves about 1) subject area to work on, 2) task to do within this area 3) where to search for information 4) time for the task 5) where to be, 6) how to present the work and, 7) how to evaluate the results. Selberg gives a view of an instructional design to use to reach student influence, where the choices of the students are important. I share her view. I stress with the concept students’ ownership of learning this third aspect of student influence of their learning. Ownership will increase motivation and thereby the communication that we find to be the central aspect of development of understanding physics. I find students’ ownership of learning to be a sharper and a more narrow definition of the opportunities a student needs to be able to learn. The student’s competence and interest at the start and the students’ ownership of learning at the start (both at group level and at individual level) will influence the motivation. We find that communication by exploratory talks and internal teaching is a part of the motivation. We find these communication possibilities during work to be a prerequisite for developing deeper conceptual and holistic understanding in physics. In the doctoral thesis “The Many Faces of School Student Impact” Forsberg(Forsberg 2000) puts forward the implications of understanding student influence as power. She finds the term “student impact” to be used to describe and understand many different expressions of influence involving students. Forsberg divides her analysis into 1) student impact from the perspective of government regulation and 2) student impact in the light of power as dominance \textbf{and} power as a unity. She defines student impact based on the view of impact to be understood both in terms of power as dominance and power as a unity.

\textsuperscript{11} SOU Statens Offentliga Utredningar
Students in class are constantly involved in relations of influence associated with what they do, how they do this and why they do this in a certain way. In this way is it not meaningful to discuss whether or not students have influence. The main point is whether the impact they are involved in has positive or negative overtones, i.e., if it is in their own interest or not. If impact is not something that students can possess then their influence is not decided by whether someone else (for instance the teacher) can step down but rather what that person does. When student impact is regarded as an expression of unity, there is nothing that precludes students and other actors, such as teachers, school leaders, school politicians and others from working together for a kind of student impact with positive overtones. (p156)

Our point of view is that students may be intrinsically motivated to fulfil courses containing different parts of tasks into which they could have different influence. They can also be extrinsically motivated to different degrees that effect their self-regulation. The obstacles do not lay in power in the class-room between teacher – students but in how traditional ways of doing things have been taken for granted to be in the students’ interest. Forsberg sees the many faces of student impact and search for analytical tools to make problematic and develop the meaning of both the concepts “influence” and “power” in the field of education. Our intention is that by the concept student ownership of learning the flavour of student influence concerning learning based on the interests of the student (in the way it happens to be) has got a name.

2.2.5 Communication

The mastery of science, according to Jay L. Lemke in “Talking Science-Language, Learning and Values” from 1990 is a matter of learning how to talk about science. The curriculum is constructed from the needs of practising scientists who present science in a rather specific way.

This does not bring science to the student, it insists that the students come to it. (Lemke 1990) He finds that the pattern of communication in traditional science classrooms, where the teacher has all the answers and evaluates how students take in the information, gives the teacher control over the students. Often students never reach a true understanding of science concepts because they are not given a common sense explanation. But already in the beginning of the 1970s Douglas Barnes studied communication and the language of the classroom (Barnes 1971; Barnes 1973; Barnes 1977). Of importance to this study is the categorisation of the small group’s talk. Barnes found that students found exploratory talk highly useful for problem solving. Barnes found that this form of talk was used when students interpret all variations of thinking around a topic and when they felt that they were so secure with each other that it was accepted to brainstorm to try to reach understanding. He found also that to the teacher the students used a talk he called the final draft. That was a description of the result of the thinking presented in as orderly form as possible.

If a teacher wishes his pupils to engage in exploratory talk of this kind, it is important to indicate this in the phrasing of the task. This is a matter of inviting a range of suggestions which the children themselves can evaluate; this emphasises the process of discussion rather than the conclusions reached. Since schools tend to emphasise ‘right answers’, children need encouragement to feel their way through difficult ideas and to explore half-formed intuitions. (Barnes 1977).

We now see it as a challenge to every good teacher to give students time for reflective thinking and the possibility to use exploratory talk to reach understanding. Exploratory talks we see as a sign of students’ motivation. See Chapter 5-7. When Barnes describes exploratory talks in Language in the classroom (Barnes 1973), he see it as the students create an appropriate mode of communication:
These discussions are very different from what usually takes place when a teacher faces a whole class. It is not only that the children are using language in a more exploratory fashion than often occurs in relative formality of the full class. It would be fair to say that they are using a far wider range of speech-roles than full-class discussion usually allows – questioning, encouraging, surmising, challenging, extending, and so on. This is possible because they have between them taken over control of the learning activity. In order to manage this they have had to collaborate: one has to draw in another; a third uses ideas from both the others. They have had to signal to one another not only the ideas they want to put forward but also invitation, encouragement, acceptance, tactful disagreement: they have had to set up an appropriate mode of communication as well as deal with the task in hand.

2.2.6  Competence
When you have competence in physics you are able to communicate physics, have skills with physical equipment and have insight in technical applications and natural phenomena. Knowledge in physics includes skill in doing laboratory work, communicative abilities and to have a holistic perspective and this is not always obvious in physics teaching books and courses. We find a need to stress this broad view of what your knowledge content is when you are competent in physics:

• to be able to talk and communicate physics and take part in scientific and everyday discourses concerning physics
• to have skills in laboratory work and experimental design,
• to have conceptual understanding and problem solving abilities
• to understand technical applications and understand natural phenomena in a holistic perspective

2.3      Operationalisation of basic concepts

2.3.1  Motivation
Milner-Bolotin finds the dependent variable of her study to be motivation, and choose to operationalise motivation as achievement goal orientation (AGO). This is an attitude towards the task defined as an interval variable ranging from mastery to performance goal orientation. Motivation as the degree of AGO is measured by the AGO questionnaire developed by Middleton& Midgley (1997). Milner-Bolotin finds that interest during the starting period of a project, by ownership of task will increase the AGO, and thereby increase learning possibilities. Savery operationalises motivation as one behavioural indicator of the affective factor quadrant in his model of ownership of learning. The affective factors can give 15/75 points in his "Checklist of behavioural indicators". Examples of Student behaviours demonstrating "Motivation balance between extrinsic and intrinsic " can be 1) examples of flow experiences 2) examples of dependent behaviours towards teacher or other person and 3) Provides reasons for taking course or doing tasks. The operationalisation of the concept motivation in this thesis is a more straightforward observation of what energy the individual puts in the work process. This energy can be observed by students' choices of particular actions, persistence with these actions and effort expanded on them (Pressick-Kilborn 2003). We use as indicators for motivation: the amount of physics talk and the amount of planning talk spent in the small group work conversation, the persistence of the work with the task, the effort the students showed in the task seen as special actions and from
communication, the existence of exploratory talks (EXP) and internal teaching (INT). Motivation is characterised by equifinality.\textsuperscript{12}

Motivation concerns energy, direction, persistence and equifinality - all aspects of activation and intention. (Ryan 2000)

By that our intention is to find a relation between students’ ownership of learning and motivation in purpose to sharpen the concept ownership.

See also Chapter 2.3.3.

2.3.2 Ownership of learning

When you start looking for ownership you see it everywhere. As an example you can ask for who has the ownership of the remote-control of TV in your family. In my family it depends on several aspects. If I have not a specific interest in a program, I do not bother to argue. Others do bother, it seems important to be the one who choose between programs. If I am really interested I do take a fight, and then I seldom loose. But it still is about power and influence...

But who has the ownership in school physics and science education? The government and education department of the country, through syllabus and physics course curriculum, yes of course. The school headmaster and the teachers through the local version of the curriculum, yes. The teacher as the leader of the class, and in control of the lessons, yes. The students - have they any ownership at all to physics in school and to their learning of physics?

What do we mean by ownership of learning? For me it has to differ from all kinds of circumstances that influence me in a broad sense, and I prefer to define it in a more narrow sense. It includes student influence to the learning situation in a specific environment. Students try to learn, but sometimes they do not get the possibility, because of their lack of influence to the situation. A common scenario is students feeling they never catch up with the speed of the teachers lectures, with the demands, they simply never get a chance to learn because the situation is maybe good for others but not for them. So I find the concept students’ ownership of learning (SOL) has to include student ownership by the instructional setting: content, question, planning, performance, result and presentation. Student ownership of learning also includes choice of partnership in groups, choice of activity concerning where, when and how. A main point is the ownership to communication: possibility to discuss with others, possibility to use media and teacher, emergence of own questions. Concerning control and responsibility: possibility to take informal leadership, to negotiate or to follow the stream. From this view ownership has to be seen as a possibility or power for the students.

Students’ ownership of learning (SOL) we find to be described in two levels:

Group level:

At start of a task is the SOL decided by the design of the task. The choice of task, the performance (when, how, where), the level of result and presentation and report have to be decided by the students themselves.

\textsuperscript{12} equifinality = It was used originally and extensively by E.C. Tolman in his early experimental work with animals on purposive behaviour, and it is emphasized as a criteria for motivation by Fritz Heider in his seminal 1958 work entitled "The psychology of interpersonal relations" (Richard Ryan 2004 0212-email contact with Hans Niedderer)
Individual level:
A person’s experiences and anomalies of understanding have created unique questions that can create certain aspects of the task that drive this person to act very active and motivated. This gives the person a high individual learner ownership.
I come back to this view in describing the methods in use to analyse the result of our investigation.

2.3.3 Communication
We analyse communication by categorising students' conversation during work, and by analysing transcriptions of special parts of the conversation. In the categorisation we use CBAV Category based analyse of video tapes, (Niedderer 2002) a technique we used also for the audio taped lab sessions. We categorised all individual talk every 30 seconds. See Appendix 3. When we transcribed the whole conversation as in the CPR groups, we categorised the sentences and counted the words. The occurrence of exploratory talks and internal teaching are given as quotations in the case studies. Exploratory talks are described in Chapter 2.3.5.
By internal teaching (INT) we mean the phenomena when a student in the small group finds herself/himself competent to teach a peer student who seems to have lack of understanding of some conceptual or contextual (holistic) understanding or laboratory or mathematical skill.

2.3.4 Competence
Competence at start
Competence is at start given as the individual test results in a physics test.
The physics test content was 22 problems that could be categorised in three aspects: 1 Mathematical problem solving, 2 Conceptual understanding, 3 Contextual understanding, (applied into technical applications or nature phenomena).
Maximum result is described as (7, 8, 7).
Examples from test:
1 Mathematical formula problem solving:
Given two capacitors 5.0 mF and 7.0mF and a 10 V – battery in series; find the final charge.

2 Conceptual understanding
An electric heat plate contents two heating elements with resistances $R_1$ and $R_2$. $R_1 > R_2$. See $R_2$ and $R_1$ as temperature independent. A switch can connect each heat element separately, or both at the same time, to a DC source with constant voltage. The four possible connections are shown in the figure. Which alternative gives the bigger power?

![Fig.2.5: Electric circuits to problem 2](image-url)
3 Contextual understanding:
Ex 1: Give an example of a practical importance of magnetic forces.
Ex 2: What are the practical use of capacitors?

In upper secondary school the problems were changed to totally 15 problems (5,5,5)

Development of competence
We use aspects of communication as a sign of motivation. We see the communication as special actions, namely exploratory talks or internal teaching together with the amount of physics talk and planning talk. But the product of motivation is development of competence (conceptual understanding, holistic understanding, laboratory work ability and ability to communicate physics), and an aspect here is competence to talk physics. This ability has to be trained, and we find every opportunity that students get to try to talk physics as important to this development of competence.

Chapter 3 The Research Process
3.1 Framing the Studies
Developing a methodology for this qualitative theory generating research project has been an ongoing process. The purpose of the main study is to search for connections between ownership, motivation and competence when students study physics in small group work in a traditional physics teaching instructional design, with inlays of MP and CRP. This very broad approach started with a pilot study with the purpose of going deeper into the meaning of the concept ownership and into the meaning of holistic perspectives of learning physics. Another purpose was to see if this PBL design had some impact on holistic physics learning and motivation to learn. In this first study students answered questionnaires with closed and open questions about different MPs, divided into different holistic categories and different degrees of ownership. At that time ownership was described as different levels of freedom in the possibility to choose and perform the task and formulate the problem solving strategy. The first study also included interviews with students in order to get a view of how they look upon MP small group work from different viewpoints.(Enghag 2002).
From this study the design for the studies reported in this thesis emerged.
The nature of the problem to be investigated was just incompletely determined at the beginning of the study and subject to change as the study progressed and therefore the design could not be fully specified in advance but rather emerged over time.
My aim was to explore what happened in small group work concerning learning of physics but also to explore and highlight actions and reactions within the groups that could explain something about what ownership is and how it is related to motivation and learning of physics. A picture of the context also certainly includes the interaction with my experiences from twenty years of physics teaching at upper secondary school, my experience of my own family and the daily company of my dog and horses and my own ability to interpret what I see. The interest in the main studies now focused on the process and communication between students video-filmed at work As I wanted to highlight what I saw more than test an existing hypothesis, the design started as inductive and explorative. But from data, theory about ownership and
motivation started to emerge. Literature studies confirmed both ownership variables and motivation variables and a structure to interpret ownership and motivation and to frame a methodology for case studies grew. It also became important to show all the differences in these group work activities. The Grounded Theory approach (Glaser 1967), influenced my view of this research as a feasible way of exploring an emerging theory. Strauss and Glaser, (and Hartman) describe how new theory generates from the interaction by theory and practice out of an exploring study based on induction. The philosopher Charles P. Peirce's (1839-1914) theory of abduction, describes the process of generating hypotheses as a process where findings have emerged as a plausible explanation that strike you from a pattern in your data that did not accord with an existing theory. The differences between, deduction, induction and abduction can easily be illustrated.\(^\text{13}\) Even if abduction is the best you find of plausible explanations, is it weaker than deduction. With this generated theory a next step can be a deductive investigation based on your new theory. In grounded theory you see theory generated in this way as an empirical theory reliable for a specific domain, a group of people. If data about the phenomena you study can be categorised and the qualities of the categories can be related, you have built a formal theory that can be tested by deduction to be general.

There are three criteria for an empirical theory: relevance, function and possibility to modify:

Glaser suggests two main criteria for judging the adequacy of the emerging theory: that it fits the situation and that it works -- that it helps the people in the situation to make sense of their experience and to manage the situation better. (Dick 2002)

In abduction the conclusion is an explanation of the observations and it is important that there is no other plausible explanation that better describes the situation. How to choose the abduction is connected to the intuitive abilities of the observer and to how signs of meaning are transferred between individuals in the context of the observed situation. (Arnborg 2003). This leads to the need to describe the pre-knowledge and perspectives of the researcher in order to describe the process of how findings emerge.

### 3.2 Research design

#### 3.2.1 Research approach

The thesis reports a qualitative theory generating (abductive) study with mutual case-studies as the method of data-collection. The background for the research process is given in Chapter 3.1.

The case-studies in the thesis are chosen from two different contexts, two MP studies from science teacher training and two MP and two CRP from physics classes in Upper Secondary School. These six cases show a variation in results and my intention is to describe ownership, motivation and competence during work process regarding nine variables that have emerged as significant. Both quantitative and qualitative methods are used to collect data into these variables.

#### 3.2.2 Research questions

The general question is:

**How** do context rich problems and miniprojects contribute to improve teaching and learning in physics?

\(^{13}\) Deduction: All dogs have four legs. Fido is a dog. Conclusion: Fido has four legs.  
Induction: My dog has four legs. Your dog has four legs. His dog has four legs. Conclusion: All dogs have four legs.  
Abduction: All dogs have four legs. Fido has four legs. Conclusion: Fido is a dog.
In the study we have to search for the answers to these questions:

- What kinds of ownership are important to be distinguished? Define the concept student ownership of learning (SOL) and give examples. Use a system of categories to distinguish different forms of ownership and discuss how the categories work.

- How can motivation be observed from students' actions during MP and CRP? Give examples and classify them. Use a system of categories to distinguish different evidences for motivation and discuss how the categories work.

- What influence do variables before and during the process (choice of actions, communication, planning) have on motivation and on development of competence and development of ownership? Explore how motivation and ownership are to be seen in small group work in physics with MP and CRP. State hypotheses concerning the relationship between ownership and motivation and development of some aspects of competence.

- Explore how the communication in the group is related to ownership and motivation.

**Chapter 4  Design and methods used in the studies**

**4.1 Methods**

The methods of analysis in use are based on the scheme for interpretive analysis of qualitative and quantitative data developed by Professor Hans Niedderer at the University of Bremen.

![Fig 4.1: Scheme for interpretive analysis of qualitative and quantitative data (Niedderer 2001)](image)
To be able to see what contributes to ownership and motivation, we made a design in order to study pre-, during- and post-activities in a group. Before starting we gave a competence test, asked for written answers to questions about views of physics and interest in physics and the tasks and tape-recorded group discussions about school physics and miniproject activities. During the MP or CRP we video-recorded the laboratory sessions at upper secondary school in 2 * 5 groups, but tape-recorded 3 and video-filmed 1 group at the physics teacher training. We also video-filmed all MP presentations and asked for their written reports or Power Point presentations. An evaluation of CRP and a questionnaire from MP were given after the presentations.

4.2 Strategy to analyse the cases

Strategy to analyse the MP:
A short case history introduces the reader into the situation. Observations from work progress are then categorised under nine variables and finally related in a model, as shown below.

Strategy to analyse CRP:
The groups’ work in CRP is first analysed in respect of how far they reach in the problem solving. Here we compare with an expert solution of the problem. They are also analysed under the nine variables given below.

Strategy to analyse ownership, motivation and competence:
From the data, from influence of motivation theory (Pintrich 1996) and from what we found to be relevant parameters we constructed a pattern of variables (I -IX).

I Ownership at start:
At group level: Choice of content, Unique question, Performance, Presentation, Results
We started to describe ownership in terms of how students have a possibility to decide the choice of task, performance of the task (as how to do, when to do this and where to be during actions). Their possibility and impact to decide on at what level they will search for results, their impact on choice of form and level of presentation and report were observed.
The possibility for the group to have a unique question became important.
At an individual level: Individual choice-vs-group choice, Choice of content, Unique question
As it became obvious that there were individual differences inside the group in aspects of ownership, it emerged that describing at an individual level how an experience or an anomaly becomes important as a unique question inside the task.

II Interest in physics:
View of School physics as quotations or pictures.
The student teachers were audio-taped when they discussed there view of school physics. The students at Upper secondary also gave pictures to show how they find physics in school.
III Interest in MP:
Preferences of MP
All students were tape recorded when they discussed in groups the different proposals to MP. This was compared to their individual choice of MP, and became an indicator to individual ownership to the task.

IV Competence: Test results in (maths) ability to perform formula calculations, conceptual understanding, contextual understanding) observations of ability to handle laboratory work
The student teachers got a test with maximum (7, 8, 7) right answers, and the younger students got a test with maximum (5, 5, 5) right answers. This profile told us what kind of strengths and weaknesses the individual students ability had at the start.

During:
V Communication aspects:
Exploratory talks, Internal teaching Y/N, Communication content: % talk divided into categories of talk, % talk divided per individual
We did an estimation of the talk in the groups by using CBAV, (Category Based Analyses of Video tapes) (Niedderer 2002) or, in some cases, to simply count words in different categories of interest. See appendix 3. The existence of exploratory talks and internal teaching (see Chapter 2.3.3) was noted.

VI More Ownership: If choice of activity (what direction next?), % planning talk of total talk
Some special activities were noted and, as a factor of individual (negotiations) of ownership during work process, we noted the amount of talk about how to plan for the task, what to do next. This is called "Planning talk".

VII Motivation:
Effort: creativity as new ideas, initiative to performance of the task
Persistence: Time spent on task, staying with the task
Intensity in doing the task :( % physics and concepts talk of total talk)
To describe motivation we started with time spent on task, intensity seen as amount of physics talk in percentage of all talk in group and effort seen as special actions and initiative they take by their interest and engagement.

Outcome:
VIII Quality of work:
Amount of work (High, Medium, Low)
Development of competence, statements
Development of self-confidence and self-esteem, statements
This became our main variable for evaluating the effect from ownership and motivation. Development of competence was seen as conceptual change and deepening of conceptual understanding or deepening of their holistic understanding. For development of self-confidence and self-esteem we looked for signs of initiative and progress during work and in presentation.

IX Quality of output:
Presentation: physics
Amount of work (High, Medium, Low); % of talk, response from audience, lab activity, impression

Products:
Report: grade, physics, creativity = (new ideas), Amount of work (High, Medium, Low), Design: (Advanced, Good, Poor)
Power Point presentation:
Physics (Advanced, Good, Poor), Creativity = (new ideas),
Amount of work (High, Medium, Low, Design (Advanced, Good, Poor)

For the quality of work we gave a simple mark-setting based on our experience of student results over many years. This gave information on the abilities of the students and indicated if any progress could be found in physics understanding and in presentation and report techniques.

Finally the variables emerged to relate in a model described as

INTEREST and COMPETENCE at start \( \rightarrow \) OWNERSHIP by group and by individual \( \rightarrow \) MOTIVATION \( \rightarrow \) COMPETENCE after
Arguments for individual analyses are given in this model. See 10.1.

During the first study (Enghag 2002) the students valued and ranked MPs that were designed with different degrees of freedom and different degrees of holistic perspective. The results indicated that students prefer freedom 2, i.e. the MP should be given as a short formulated task without specification of how to perform the task but with a sharp question. "How many tracks are there on a CD?" was a typical MP task that students choose. How students in these studies viewed different MPs is reported in Chapters 5.1 and chapter 6.1.

4.3 Instruments
All the different instruments in use are named and listed in APPENDICES 2-3.

4.4 Choice of groups to be included for the thesis
All groups shaped very different MP. The student teachers The Transformer Group was chosen as there were obvious differences of ownership at the individual level in group. At Upper Secondary school we found the female group of special interest as they so clearly demonstrated conceptual change, The Electric Circuits Group. The group consisting of low performing students was also especially interesting - what happens when you give freedom to approaching a task to low performing students? To compare MPs and CRPs we also used the same groups in this task also. We will report the results from more CRP groups later

Chapter 5 Results of case studies with the student teachers
5.1 Overview of MP for student teachers
At the start the student teachers 1) discussed in groups a list of 20 proposed MPs, including number one, a totally free choice. Then they were 2) asked to individually grade the MPs with respect to how interested and motivated they felt to choose a specific MP. They graded the miniprojects in a Likert scale from 1 to 6 where 1
stands for “No, very little” to 6: “Yes, very much”. Finally 3) they made an individual choice of MP to work on.

Fig. 5.1: Students Interest in 20 MP divided in categories. Mean Values from Likert scale.

The student teachers were positively interested in most MPs but preferred and ranked MPs from the categories of technical applications and natural phenomena higher than other MPs. Verifications of physical laws were ranked low in general. The tendency was to give high scores to MPs that strengthen the holistic understanding of physics. All mathematical problem solving was avoided. This could be an effect of the possibility to grasp the meaning of the MP at first but also in students' statements they expressed a need for holistic and contextual understanding and “fewer calculations.” They finally choose these MP:

1. The Thunders – phenomena in the electric field around the Planet Earth.
2. Illustrate the transformer and transform voltage and current.
4. The Earth’s magnetic field – The Sun Wind – van Allen Belts
a) To decide the horizontal component of the Earth’s magnetic field.
b) Explain why the earth’s magnetic field protects us from the sun’s radiation.
c) Give an image of the extent of earth’s magnetic field.
d) What do declination and inclination mean?

5 Make an electric motor and explain how it works.
Wind insulated (why?) copper wire around a cylindrical object so you get a winding with about 10 revolutions. Take the winding away and fasten the ends carefully. The winding must be perfectly equal to be going around in balance. Let the ends of the winding be the axle of the motor. Scratch the insulation from one end. The other end has to be scratched only along half side of the wire axle. Let the axle rest in paper clips fasten in a piece of “frigolite”. Put a magnet under the winding and connect a battery to the paper clips. Help the motor to start with a push.

Fig 5.2 The Electric Motor Model

5.2 Case 1 - The Transformer group at Science Teacher Training
5.2.1 Overview of the case
PRIOR:
Mattias 48 years, Kenneth 30, Jonas 40 and Markus 34 work together for two weeks with the Miniproject Illustrate the Transformer – transform voltage and current. The students would like to strengthen their holistic understanding of physics. They share a view that school physics has to include more practical moments to become interesting and meaningful for the students. They find miniprojects an interesting tool to broaden the physics context and make physics coherent with general knowledge of nature and society. They fear the time pressure of the demanding course. They expect their MP to be interesting and fun.

DURING:
They all meet in the laboratory in the morning of the day of the lab session. They start by looking at some websites they have found earlier. Mattias and Markus almost immediately come into deep conversation about physics concepts related to the transformer. They all then discuss with the teacher and take advice in getting relevant books to begin with. Their strategy is to start with easy experiments from schoolbooks with coils and magnetic fields and then go on to experiments with transforming. Kenneth brings a commercial transformer into school, which is a gift from his father. He likes the idea of showing it to others to see how it is in reality. Mattias and Markus continue discussions to deepen their understanding of the physics of the transformer. Mattias tries to explain and Markus gives him sharp questions back. They talk in a strange way with half sentences and incomplete and improper ways of expressing physics but they seem to be very engaged in really trying to understand what is going on inside the transformer. Kenneth sometimes joins them. Kenneth and Jonas start to
make experiments and try to understand the equipment and instruments that are available. When it comes to the theory of physics and mathematics Markus always seems to be involved. Jonas shows interest in the instruments. Together they make a series of measurements of transformation of voltage and current. They fail to see a pattern at first. The next day they have found easy descriptions of the relations between voltage in primary and secondary sides making an assumption that there are no losses. Mattias confirms that he has found it both on a web site and in his son’s schoolbook. Kenneth and Mattias have formulated their own questions concerning the transformer that emerge during lab sessions. They are discussing the question if there are current losses in the transformer when it has no load on the secondary side. It gets hot even if there is nothing on the secondary side. Mattias offers the hypothesis that transformers become hot even without charge on the secondary side because of energy losses inside the transformer. Jonas helps him with the instruments. They fetch a new instrument especially to test Mattias hypothesis. The new instrument measures power consumption and energy turnover with two digit accuracy. Mattias finally takes the instrument home with him. When making the presentation in PowerPoint Jonas helps Mattias with it. Jonas thinks they are going too far in searching for the energy losses.

OUT-COME:
The group present their results in an oral presentation based on a PowerPoint presentation. Mattias is leader of the presentation and starts with an overview of the presentation design. Markus begins with a holistic view of the transformer in society, and electricity distribution into households. He also explains a simple mathematical theory of the transformer. Kenneth and Jonas verify the theories by experiments that transform voltage at different settings. Mattias continue with an explanation of the group's reflections over energy losses and measurements from their investigation. Their PowerPoint presentation is excellent. The response from audience is good with questions and discussions.

5.2.2 Results
Prior:
I Ownership at start:
Performance and presentation are free choice
The possibility to decide content, question, performance, presentation and result are given to the group. The setting gives the group high ownership.

The individual choice of MP versus the final group choice of MP.
They express in the initial talks before they formed their final MP groups thoughts that became signs of what should come:

(1)
Markus: I find this interesting too. Make a strong electromagnet and decide it’s capacity to lift. That is number 19. You will need a good battery, and..., some iron stick...
Mattias: I was thinking on this... and than I found some thing I did not understand...The transformer.... it started with my son he got current in himself because of a torn transformer.....and nowadays we have those small transformer all over the place...inside every electric things...when it is not 230V there is a transformer somewhere -I think it could be fun to think of it...
Mattias: And it is as usual, you can start with a thought and it will end up with another, you get impressions during the way...
Jonas: Everyone has something of their own.
They all finally choose MP nr 14, the transformer. They did not all rank this MP highest in the first discussion:
Mattias did give highest rank 6 only to the Transformer MP and Kenneth gave also 6 to nr 14, but also to six other projects. Jonas had preferred MP nr 19, in fact he ranked the Transformer MP low only 2 of 6 to nr 14, the Transformer MP. Markus gave 5 to nr 14, the Transformer MP but 6 to MP nr 15, 17 18.

II Interest in physics:

Students express that they would like to strengthen their holistic understanding of physics. It is important to students to find the connection between physics concept and the context where they are found: technical applications and nature phenomena.

Students like to include more practice into physics education.
They share a view that school physics have to include more practical moments to become interesting and meaningful for the students.

(2)
Markus: Practical moments are underestimated. I find them to be of great value. I believe that you learn a lot when you are at work by yourselves, and you see how it works.

Kenneth: I found it fun with experiments, it was interesting.

Kenneth: Yes, it is important to do it practical, not only in theory. They need to understand it practically, I mean they have to understand what it is all about, not only be sitting and prepare one's homework as formulas.

Kenneth: You get some time to breath when you do experiments so you can think yourself
Markus: Because I think it gives me a lot when I can make experiments myself and find out how it works.

Markus: Well, now I feel stress when we do ordinary lab sessions, if you don’t manage to do everything in time. You can not sit down and think, because then you don’t manage all of it.
Markus: Studies in physics were pretty theoretical, weren’t they? We did experiments but... I like to do experiments. I should prefer more experiments and less writing reports.

Kenneth: No, I think it is good to learn how to write.

Markus: The practical moments are under estimated. I think they are worth a lot.

III Interest in MP:

They find miniprojects as an interesting tool to broaden the physics context and make physics coherent with general knowledge of nature and society.

(3)
Markus: I find it excellent. I think teaching should include more of this. Maybe you miss something if you broaden yourselves instead, but you need to broaden yourselves.

Fear of time pressure decreases their interest in the MP.
They fear the time pressure of the demanding course.

(4)
Markus: I have apprehensions – time pressure.
Jonas: Yes, it has to be reported within a week, one week full time studies, it is so?
Kenneth: It will be a fight when you also have two lab reports to do.
Their final choice was formulated:

(5)
Markus: I am interested in how electric energy are transferred from industry to houses and in how the transformer works. I like to have an holistic perspective on things.
Kenneth: This is something that are used out in reality. Could be fruitful to know how a transformer works in a transformer station for example, and how a transformer station works itself. How current reach the households.
Jonas: This subject seems to be the most interesting and that makes it more fun to work with.
Mattias: We are surrounded by transformers. They stand for a increasing part of current consumption. I should like to have impact in this in aspects of the environment, and how are allergic persons affected?

IV Competence:

The competence test was given before the MP start. It was divided into three parts. The test included seven mathematical problems of formula solving character, eight problems that needed conceptual understanding, and seven theoretical questions concerning contextual understanding, e.g. Max (7, 8, 7)

As individuals they were different. Mattias had the result (4, 7, 5). Markus reached (6, 8, 5). Jonas had (4, 1, 1) and Kenneth (5, 5, 2). It seems from these results that Markus has high competence in physics in all aspects, Mattias is not that good in math but in holistic understanding, and Jonas has low results. Kenneth showed low score in contextual understanding but good in the math solving and conceptual understanding.

During:
V Communication:

Exploratory talks:
They use exploratory talks to reach understanding.
Mattias and Markus almost immediately come into deep talking about physics concept related to the transformer. Mattias try to explain, and Markus gives him sharp questions back. They talk in a funny way with half sentences and incomplete and improper way of expressing physics, but they seem to be very engage to really understand what is going on inside the transformer. Kenneth sometimes joins them.

(6)
Markus: Now those two times each other…
Mattias: become as much as on this side…
Markus: Yes, then you will get a lower voltage in this and will you get a higher current then…?
Mattias: Yes. So it is. And it is because of induction then as it is transferred…They do not touch here….
Kenneth: It creates a magnetic field then…?

Internal teaching:
Internal teaching can develop into exploratory talks, if the learner responds with good questions. Mattias who has confidence in his understanding of the transformer start to teach Kenneth. As Kenneth ask questions that Markus can’t answer the conversations comes into an exploratory talk.
Communication content:
Amount of talk divided into categories.
The total amount of audio taped talk was 180 minutes. It was divided in seven
categories as below.

![The Transformer Group Amount of talk divided in categories](image)

<table>
<thead>
<tr>
<th>Categories</th>
<th>Number of marks</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics talk</td>
<td>88</td>
<td>9,7</td>
</tr>
<tr>
<td>Exploratory talks</td>
<td>104</td>
<td>11,4</td>
</tr>
<tr>
<td>Physics concepts</td>
<td>293</td>
<td>32,2</td>
</tr>
<tr>
<td>Instrument talk</td>
<td>201</td>
<td>22,1</td>
</tr>
<tr>
<td>Math talk</td>
<td>40</td>
<td>4,4</td>
</tr>
<tr>
<td>Non-task talk</td>
<td>39</td>
<td>4,3</td>
</tr>
<tr>
<td>Planning talk</td>
<td>146</td>
<td>16,0</td>
</tr>
<tr>
<td>TOT</td>
<td>911</td>
<td>100,0</td>
</tr>
</tbody>
</table>

Fig 5.3: The total amount of talk divided into the categories.

The amount of physics concept talk is 32% of the total amount of talk, the highest
amount of all categories.
The total amount of talk divided into the members showed that Mattias talked 35% of
the time, Markus 28%, Jonas 12% and Kenneth 21%. The teacher talked only 4% of
the time. Your competence influences your ownership of the conversation is a
possible explanation of this.

**VI Ownership:**
Choice of activity:
Students go back to basics to understand.
They start to review measurements they made the first day when they studied voltage
transformation in several experiments. They don’t understand the connection between
wire turns and voltage at first. They search for help in books that are easy to
understand.

(8)
Mattias: I looked in the first chapter of the book yesterday. The oldest son had a physics book with
him from school.
Jonas: What class?
Mattias: He is in the ninth...It said that if you double the turns on secondary side you double the
voltage there..
Kenneth: Ok
Mattias: And than when I see these measured values from yesterday….I thought that…
Kenneth: Then we had less voltage but more current

They develop own hypotheses.
Mattias question why transformers get hot even without loading on the secondary side
drives the group forward. Mattias and Jonas try to measure the energy losses. They
find no sign at first. Jonas understands the instrument and increases by that his
ownership. Mattias believes in the hypotheses and he doesn’t give up. He finally takes
the instrument home with him.

(9)
Mattias: Haha haha It looks like you can get the costs directly on the display…!
Jonas: Energyprice – we don’t have one - what is the energy price – I don’t know that…we don’t have
any…
Mattias: No, but the point is to try to find….why has it stopped here ?
Jonas: But you have turned off the lamp, haven’t you?”
Mattias: Is it that miserable?? Is it that miserable?? Has it to be that miserable???
Jonas: But it is off isn’t it? You have turned the lamp off! The energy will only go when the lamp is
on you see.
Mattias: Yes, but my point was to show that there are energy losses even when the lamp is off…”
Jonas: OK, but it couldn’t be there is no energy losses - then you have to put it There directly
the instrument otherwise you turn it off too...
Mattias: Should it be here you mean…
Jonas: Yes, now you understand how it works, but there is still no energy consumption, it
stopped…at least no measurable…
Mattias: No, it should be like this…it can go there for a while…”
Jonas: But on the other side ….if it can stays there for 35 hours or something…
Mattias: Yes, we let it on then…
Mattias: No I thought it would be miserable if….
Jonas: But is it miserable if it doesn’t take current when..!!!

Amount of planning talk divided into individuals:
The amount talk about planning what to do was 16% of all talk.

Amount and Percentage Planning talk /person

<table>
<thead>
<tr>
<th></th>
<th>Mattias</th>
<th>Markus</th>
<th>Jonas</th>
<th>Kenneth</th>
<th>Teacher</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marks</td>
<td>60</td>
<td>32</td>
<td>17</td>
<td>37</td>
<td>0</td>
</tr>
<tr>
<td>%</td>
<td>41</td>
<td>22</td>
<td>12</td>
<td>25</td>
<td>0</td>
</tr>
</tbody>
</table>

Amount of talk in categories/person in The transformer Group

![Amount of talk in categories/person in The transformer Group](image)

Fig.5.4 Amount of talk in categories/person in the transformer group
P=physics talk E= exploratory talk C= concepts talk N= instrument talk
M= mathematics talk W=non-tasks talk Pl = planning talk
Mattias was dominant (41%), but they all contributed quite equally in this category (Markus 22% Kenneth 25%). Jonas contributed much more to the planning (12%) than to the physics talk.

VII Motivation

Effort:
There are several signs of effort. One is when Kenneth brings a private transformer into the lab session to see how it works in reality. Kenneth shows us a transformer he has got from his father to bring into the miniproject.

Kenneth: I have got it from Dad. He works in a car firm and they expose car stereo apparatus. Then they take 230V and make it 12V for the car stereos. But it is not only the coils and magnets it is a thousands of other things too…”

Teacher: Well yes, this is a rectifier …mm…that is interesting of course...

Kenneth: Yes. Unfortunately you can’t see the coils.

Another sign of effort is when Mattias and Jonas go into the investigation of energy losses and do the investigation at home.

Persistence: The group audio-tape their talk over 180 min of their lab-sessions. The preparation of their presentation is only partly included here.

Energy put in during process:

<table>
<thead>
<tr>
<th>Talk of Physics concepts/person</th>
<th>Numbers of marks</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mattias</td>
<td>111</td>
<td>37.9</td>
</tr>
<tr>
<td>Markus</td>
<td>87</td>
<td>29.7</td>
</tr>
<tr>
<td>Jonas</td>
<td>15</td>
<td>5.1</td>
</tr>
<tr>
<td>Kenneth</td>
<td>71</td>
<td>24.2</td>
</tr>
<tr>
<td>Teacher</td>
<td>9</td>
<td>3.1</td>
</tr>
</tbody>
</table>

Table 5.3: The total amount of physics and physics concepts talk divided into the members.

Mattias talked 35% of the time, Markus 28%, Jonas 12 % and Kenneth 21 %. The teacher talked only 4 % of the time.

The group have reached an understanding of the basic principles of the transformer. They have done several experiments to show basic properties of magnetic fields around charged current wire and coils. They are excited and enthusiastic over their discovery of energy losses. They go for this task with high expectations of reaching good results.
OUT COME:

VIII Quality of work:

Amount of work
The student teachers work hard with almost no non-task talk at all. They use all lab session time and do much work at home, even lab work such as measuring energy losses in domestic transformers.

Development of competence
The second day they have found easy descriptions of the connections between voltage in the primary and secondary sides, assuming that there are no losses. Mattias confirms that he has found it both on a web site and in his son’s schoolbook.

Mattias: I looked in the first chapter of the book yesterday. The oldest son had his book with him from school.

They are discussing the question if there are current losses in the transformer when it is not loaded on the secondary side. It gets hot even if there is nothing on the secondary side. Mattias offers the hypothesis that transformers become hot even without charge on the secondary side caused by energy losses inside the transformer.

They got a new instrument especially to test Mattias's hypothesis. The new instrument measures power consumption or energy turnover to two digit accuracy. Even in the final presentation the motivation coming from this special ownership can be seen in decisions and persistence with special actions.

During the presentation Mattias continues with an explanation of the group's reflections over energy losses and measurements from their investigation.

Kenneth and Jonas show the experiments during the presentation and explain what Markus has shown theoretically:

Jonas: OK. We shall nowe by apllying a low voltage here.
Kenneth: We have 600 turns in the primary coil and 12000 on the secondary. a ratio of 20. Then we test here with...that's not quite perfect....
Jonas: 1.7 V in the primary side 30V....yes 20times. Can somebody check on a calculator 1.7 times 20...yes 34 V if it was exact
Kenneth: You never get exact values with multiples..
Student: Can you turn it up a bit?
Kenneth: Sure
Jonas: 3V and 54V
Kenneth: That isn't quite right. We have lost something....

Kenneth said in the initial discussions about MP that he was interested in transformator plants:
Kenneth: Yes, number eight looks interesting... Transform the current... what do we do after that... do we bring a power transformer into the classroom? Laugh?

He comes back to this issue during presentation but now he knows what they are used for:
(15)
Jonas: Where and how are transformers used? We use them many places. They are used in lamps and plugs.
Kenneth: ((Interrupts Jonas) We use them to reduce the energy loss during transport all over the country.
Jonas: We use them at home too...
Kenneth: The largest portion of the country uses 400 kV and then it goes to a transformer plant and ends up being 230V.

Development of self-confidence and self-esteem

Markus goes from internal teaching to exploratory talks with Kenneth. He has a strong position in the group from his strength and ability in theory. He does the calculations and shows the mathematics behind transformation in the presentation. Kenneth develops self-esteem during work. He forces Markus into exploratory talks by his arguments.
Jonas cooperates with Mattias helping him with the instrument that measure energy losses. He gets appreciation for this and sounds self confident and happy.

Mattias communicates easily with them all as he has the ownership of content and question. This gives him the initiative and he can suggest what to do next.

IX Quality of output:
Presentation:
Creativity=(new ideas): YES;Amount of work (High, Medium, Low): HIGH
Response from audience: YES;Lab activity: YES;Impression: VERY GOOD
Time: 20 minutes; % of talk (number of words in transcript of presentation)
Table: Number of words in transcript of presentation

Products:
Report: A PowerPoint presentation (advanced);Amount of work: High;
Design: Very Good;
PowerPoint presentation: Very Good; Physics: Very Good; Creativity: YES

5.2.3 Summary
Interest in physics
Students find physics interesting but demanding. Their memories from school physics in secondary school are that it was fun and interesting. Only Markus had done upper secondary school as a student in the science program. They all have had physics at A-level at “KomVux” - adult education.
Interest in MP
They share a view of the importance of practical laboratory work and they all like to deepen their holistic understanding. Mattias and Kenneth focused directly on the transformer MP but Markus was interested in the electromagnet MP and Jonas found it uninteresting. To stay within the group is important to Jonas. Markus finds any project concerning electric supply in society interesting.

Ownership at start
The instructional design gives the group high ownership to the MP. They choose an activity concerning where, when and how. The students are free to work in the way they prefer. Mattias and Markus start to discuss how a transformer works. They sit in front of a computer and look at an image of an outline of a transformer. They are talking two and two. Jonas and Kenneth start to investigate coils and iron cores. They all work with concentration and intensity. There seems to be no leader in the group, they all start with their different activities. They are free to act and talk, to sit still or move, to do their activities when they like. On an individual basis is it Markus and Kenneth that have earlier experiences and incidents that make this a unique question to work with. Jonas, whose strongest argument is to be a member of this particular group has low ownership at the start.

Competence
It seems from these results that Markus has high competence in physics in all aspects, Mattias is not that good in maths but in holistic understanding and Jonas has low results. Kenneth showed a low score in contextual understanding but was good in the maths solving and conceptual understanding.

Communication
They use exploratory talk and internal teaching. The group talk is divided into individuals, so Mattias takes 35% of all talks noted, Markus 28%, Kenneth 21%, Jonas 12% and the Teacher 4%. Mattias and Markus have physics concepts discussions together and both have physics concepts discussions with Kenneth. Jonas talks a lot more when it comes to instruments and how they work, and then he has the same amount of talk as the others.

The communication consists of exploratory talks, internal teaching, use of media and teacher. Emergence of own questions are shown.

Mattias and Markus are “back to basics”. They have found a book from high school were transformer power is said to be equal on primary and secondary sides. They discuss this in an exploratory talk (Barnes 1973). Kenneth can easily join the conversation too. When the group starts to prepare experiments for their presentation Mattias still drives the question of why his son got burned on the transformer. Why is the transformer hot, even without any lamp on the secondary side? Does it take energy without doing any transformation? Can one measure the energy losses? The group has a new instrument to measure power consumption or energy turnover with two digit accuracy. They are discussing the question if there are current losses in the transformer loaded on the secondary side. It gets hot even if there is nothing on the secondary side.

Mattias is very keen on investigating this issue. He has got the hypothesis that it is the iron itself that causes energy losses. They connect the instrument. He has a
hypothesis. Jonas shows his strength in understanding the function of the new instrument. If Mattias has the ownership of the question and this emerging hypothesis, Jonas has ownership of the instrument. Mattias doesn't try to take it from him. He needs all help to show these energy losses. He finally succeeds in showing this.

Motivation and ownership during work.
Some special activities seen: They choose to go back to basics before they understand the transformer. They also develop their own hypothesis which leads them to their own investigations. They meet difficulties but they manage to solve them and go on, they show persistence with the task. The non-task talk is 6%, so they are totally focused on the task. This group includes people with different abilities and strengths. This gives them ownership of different aspects and a well functioning group. No informal leadership is seen. Mattias has ownership of the question and inspires the group with his enthusiasm for the transformer. Markus has ownership of the theory and mathematics. Jonas has ability with the equipment. He has not the language to express all of his knowledge but he has a mission in getting the instruments to function. Kenneth mediates between the different activities in the group and with the teacher. He becomes important for the experiment setting and structure in the group.

Quality of output
The quality of the oral presentation and of their PowerPoint presentation is very high. They show increased conceptual understanding and increased contextual understanding. The amount of work is high.
In the final presentation their individual characteristics are shown:
(#I-E2.2)
Mattias: In this MP have we been working with the transformer...
(The other group members start to connect electric circuits with coils and instruments.)
Mattias: We will start by telling you about how the transformer works. Then Markus will talk about the function and the theory behind it. Then Kenneth and Jonas will show you demonstrations that strengthen the theory and finally we will present the reflections we have about transformers.
They end with an interesting and unique view of the transformer in a nice Power Point presentation.
5.2.4 Discussions about evidence

Mattias talks already in the first group discussions about the mysterious transformer. When he finds it among the 20 proposed MPs he immediately wants it. He finally chose it. Mattias has the personal experience of his son. (#(1))

... You know – the transformer – it is because the kid he got a shock when the transformer was broken.
Mattias choose the MP he gave the highest value score.

(#{5})

We are surrounded by transformers. They represent an increasing part of current consumption. I should like to have impact in this in aspects of the environment and how are allergic people affected?

Mattias chooses his own content and his own question, which gives him a special and high ownership. Mattias has high physics competence in all three dimensions of mathematical problem solving, conceptual understanding and holistic understanding of everyday contexts. He shows interest in more holistic contents in physics teaching and expects that to happen in mini-projects. He shows a special ownership of questions related to an experience of his son with a transformer. This kind of very personal ownership leads to specific motivation determined by this ownership. The other preconditions of interest and competence are seen to have positive effects on the quality of work of Mattias and of the group as a whole.

In the case of Mattias, some direct consequence of ownership on motivation can be seen. His ownership comes from the idea that his son's experience has to do with energy losses on the secondary side. His motivation from this ownership can be seen in many special actions he decides to do or to suggest to the group:

- He decides to look into the web and into his son's schoolbook
- He suggests doing experiments to analyse energy losses, even after they found the assumption of no energy losses in another physics book. That means he shows some persistence with this action.
- Mattias continues with an explanation of the group's reflections over energy losses and measurements from their investigation.
- Mattias is leader of the presentation and starts with an overview of the presentation design.

There may be a special explanation of the large contribution of Mattias in conceptual physics talks (38%).

The high percentage of Mattias's contributions on planning talks might be an effect of competence and ownership. Mattias takes part in the planning of work. He has 41% of the talking in aspect of planning. This is a sign of motivation, both in aspects of effort and persistence. In presentation Mattias show a developed understanding of the transformer. He has strengthened his conceptual and contextual competence.

In discussions before the choice, Mattias showed interest in transformer for a specific reason:

I was wondering about this and then I realised that I did not understand this - You know – the transformer – it is because my kid got a shock when the transformer was broken – we have those small transformers at home lots of them in every electric object. When it is not 230V then there has to be one – so I was thinking – It could be fun to think about it.

When students continued to discuss twenty proposed miniprojects Mattias showed interest in the transformer:
Mattias: And now number 14- as you understand- yes this I am interested to do-the transformer
Kenneth: Mattias – now it is for you
Mattias: Yes, I can go for this
Kenneth: – to illustrate the transformer...
He found it possible to work with his own question as the proposed miniproject was wide enough to allow that. The other group members showed the same or similar interest.
Markus: I was wondering as a proposal of my own to build an electric motor- but now I see the list a proposed miniproject that is about building a motor of your own- so I wonder if it isn’t for me. It is number 15.
Kenneth: Yes, number eight looks interesting. Transformation of current.. What does one do then?...Shall I bring some switchgear into the classroom and show? Ho-ho.

The causal relation for Mattias:
**Interest** in holistic perspective and in MP and **experience** of transformers by his son’s accident
→
**Ownership by the choice of an MP**: high ownership to a unique question based on experience with his son, ideas of energy losses
→
**Motivation**
- high competence (highest points in context understanding)
- communicate intense with the others,
- is the prime mover to analyse energy losses in an own investigation
- high amount of physics conceptual talk
- high quality of contributions to work and presentation
→
**Competence** as development of conceptual understanding: His investigation gives him new conceptual understanding concerning the energy losses in transformers.
Holistic understanding: Of current supply in society and of choice of material in transformers but also by using advanced PowerPoint presentation. Communicative ability as leader of the oral presentation, and all exploratory talks with his friends in the group.

Kenneth also expresses interest in the transformer from the beginning. He is open-minded to other projects as well. Kenneth valued the transformer MP highest, but gave also to highest value to six other projects. But he mentions several times the word switchgear which shows that he has an own question there. What is a switchgear? When the miniproject group start their first session in the laboratory Kenneth has brought a transformer with him that he has got from his father. He gives it to the school as a gift.
(#10)
Kenneth: You , this one is for you...if someone another year wants will try it...
Teacher: Well, that’s fine!

Kenneth has clear ownership of the content from the very start, and takes initiative immediately to action, which we see as a sign of motivation. He has expressed interest in doing experiments that were fun in school physics earlier. He now takes initiative in building up all kind of experiments and h together with Jonas he shows them in their presentation. This we see as a sign of connection between interest and
ownership. Kenneth did not get a high score in contextual understanding, 2 out of 7. Maybe this can strengthen our belief that students choose intuitively tasks that are needed to develop their understanding. Students can have a conviction to bring into the light a view of a problem they have found as an anomaly in their thinking about physics phenomena. Kenneth takes only 15% of the talk about physics in general but 24% of the talk of physics concept. This is a sign of his ability also seen at test result at the start; he is strong in conceptual understanding. Kenneth shows signs of personal development during the presentation; he gives a strong impression in his view of transformers in society and in his dealing with experiments and equipment.

The causal relation for Kenneth:

**Interest** to explain physics phenomena.
- interest in holistic perspective, practical experimental work and in MP
- physics competence (high points in conceptual understanding)

→

**Ownership**
- high ownership to a question based on curiosity of transformer stations

→

**Motivation**
- choice of experimental work
- effort by taking a private transformer to school
- high amount of physics conceptual talk (24% of all conceptual talk but 15% of physics talk)
- communicates intensely with the others also in exploratory talks

→

**Competence** as development of conceptual understanding seen in presentation, holistic understanding, communicative ability.

**Jonas** give his motivation

(#(5))

This was the most interesting, that makes it more fun to work on

But in his individual value he gave a low score to this MP. Jonas himself had valued a different choice of MP (# 19) highest but his group agreed on MP14 (the Transformer MP). For Jonas it was important to be in the same group as his friends (ownership questionnaire #18). Jonas, Mattias, Markus and Kenneth are friends from other courses. To work together is important. In the beginning of the group work, Jonas did not say much (8 statements compared to 84 from another group member). We interpret this as a result of small ownership of content and question. But then the work came to measurements he seems to have developed more ownership: That resulted in considerably more contributions from him in the next phase (44 contributions compared to 65 of the same student as before), an increased motivation.
### The causal relation for Jonas:

**Interest**
No interest expressed in holistic perspective and in MP but interest in experimental work. Low competence in theoretical test. Competence in laboratory equipment and experience of measurements.

→

**Ownership**
No individual ownership of content and question at start. Likes to join the group. Competence in laboratory equipment and experience of measurements. Ambitions to develop physics understanding.

→

**Motivation**
Jonas shows low contribution to communication 6% of all talk and 12% of planning and 12% of physics talk but he increases his motivation when it comes to measurements. This is due to his ability with instruments. He also shows motivation in use of computer programs such as Excel and PowerPoint and to show laboratory work during the presentation.

→

**Competence** as development of conceptual understanding, holistic understanding, and communicative ability are seen. We find some growth of self confidence - as seen at the presentation.

---

#### Markus give his motivation:

(#(5))

I am interested to see how electricity is supplied to industry and households and of how the transformer works. I like to have a holistic view of things.

But Markus gave 5 to nr 14 but 6 to MP nr 15, 17, 18.

It seems that Jonas and Markus put being in the same group as their friends before ownership of content and question. Markus, who wanted to work with the electric motor in the early discussions, has changed his mind. Markus seems to have another kind of ownership, he is a good theoretician, and he often gets involved in discussions over the physics concepts and mathematical expressions often. This can be seen in his amount of physics talks (30%) compared to Mattias (40%), Jonas (5%) and Kenneth (25%), and in the fact that exploratory talk involves Markus.

### The causal relation for Markus:

**Interest**
- interest in holistic perspective and in MP

→

**Ownership**
- no ownership to a direct question, but ownership to the task because of his ability in physics and general high competence

→

**Motivation**
- communicates intensely with the others also in exploratory talks
- high amount of physics conceptual talk
- choice of theoretical reasoning with physics concepts
5.3 Case 2 - The Electric Motor group at Science Teacher Training
5.3.1 Overview of the case
PRIOR
Three women Eva, Manuela and Marianne aged about 35 come together to build a model of an electric motor. They will become teachers in secondary school and like to find easy, practical and enjoyable experiments for students in the lower ages but they have never made an electric motor themselves and they would like to take the opportunity. They have big families and they fear this will take too much time but they express how much fun they find it as well.

DURING
OUT-COME:
They show their best motor model during presentation. They did not succeed with their PowerPoint presentation and did not ask for help because they were out of time. Their presentations are personal, unusual and include reflections over physics content in school, purpose of physics and purpose of technology in society. The physics content is not perfect, the function of the motor is still a bit unclear but they have reached their goal, the motor spins nicely.

5.3.2 Results
Pre conditions:

I Ownership at start:
The group choose the electric motor. They are the only group doing this MP so it becomes a unique task for the group. Eva focuses very rapidly on this MP, but they all agree on doing this practical task that will be useful in the future as physics teachers in secondary school. They like the idea with the MP, but they are critical of the time pressure.

(1)
Marianne: But this is 40 hours and we only get 20 hours. We don’t even get the theoretical time.
Eva: And then you can give us MP earlier so that we have a chance for reflection. I am the type of person that likes to reflect over things and I wonder about things. After that I continue my work. I might take the first lesson for 7 weeks so I can get it. Then I can go there.
Manuela: One should be given a reasonable amount of time to do a good job.
They are very focussed during the lab session. They want the motor to spin, they would like to make some good copies to have for their presentation and take the arrangements for the presentation the other day. The have decided to do the PP presentation and they make a strategy for their presentation that is not recorded.

The individual choice of MP versus the final group choice of MP.

They gave this MP highest value in the individual ranking about all MPs. They all choose it individually as well.

II Interest in Physics

They agree that physics is fun but difficult. They mention again their lack of time.

Manuela: I have experienced physics as fun but difficult. Specially if there isn’t enough time to go into it deeply. I think it is difficult. You have to spend a lot of time to get into it. Otherwise it’s fun, when you have learned and you understand what it is all about. It’s great it is about all that is around us.

Eva: Yes, I have always thought it has been fun...

They also emphasize the importance of communicating physics and arousing curiosity and showing connections to the world around us as the main argument to students to get them interested in physics.

Marianne: To discuss.
Eva: The most important thing is to make the subject enjoyable and awaken curiosity. If you can awaken curiosity in someone they can continue on their own.
Eva: It should be related to the real world otherwise it becomes too abstract for them.

III Interest in MP:

They choose this MP from interest and its usefulness.

Manuela: It seems interesting and fruitful. To see in practice how a motor works.
Eva: It looked interesting! Rewarding to see how a motor works. As a lab session it can be fun also for lower ages. Close to reality.
Marianne: Something that is used in real life and which you come in contact with every day. Can be shown in practice easily.

In the start discussions about the MP show that girls do not find it easy to reach understanding about electric motors and that this will be a fun activity for students in school.

Marianne: Yes, I think pupils find this fun too.
Karin: Yes, I think so to. Than they see that you have use of physics in reality.
Marianne: As a girl - a motor- even up in ages- that was something you had no idea about how it looked inside or worked – you should take this chance...

IV Competence:

The physics test with seven questions in calculations from formulas, eight in conceptual understanding and seven in holistic understanding could give maximum
(7, 8, 7) points. The three female student teachers got: Eva (3, 5, 2) Manuela (1, 2, 2) and Marianne (6, 5, 2). The test results show some weakness in the holistic understanding especially. Marianne shows the strongest results.

**During:**

**V Communication** aspects:

Exploratory talks

Exploratory talks can be seen between Eva, Manuela and Marianne when they try to understand the physics of the electric motor. Eva is satisfied with having initiative to the work and to see the motor spin. She is not as interested as the others in going into the question of why it works, to understand the physics behind it.

(6) Marianne: Contact…no contact…maybe it is not switching direction.
Eva: It keeps loosing contact…and every time it does it stops the current.
Manuela: And why does it spin? It must be the magnetic field…
Marianne: It has to align itself with the magnetic field…
Manuela: The current goes this way and the magnetic field goes this way…it is influenced by a force.

Manuela shows the right-hand rule but is unaware of the permanent magnets field alignment and seems to believe that the force is produced in the current-carrying wire without influence from the external magnetic field.

(7) Marianne: But then the force goes in this direction…? [...] Marianne: Listen!!! Isn’t it like this! It tries to get into equilibrium. But if we keep turning the current off and on all the time a force is induced. When we had this thing with the magnets and conductors it was…
Manuela: Yea, that’s right…

**Communication content:**

<table>
<thead>
<tr>
<th>Category</th>
<th>Eva</th>
<th>Manuela</th>
<th>Marianne</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics</td>
<td>166</td>
<td>165</td>
<td>88</td>
</tr>
<tr>
<td>Expl. talks</td>
<td>36</td>
<td>8%</td>
<td>18%</td>
</tr>
<tr>
<td>Concepts</td>
<td>88</td>
<td>18%</td>
<td>0%</td>
</tr>
<tr>
<td>Instruments</td>
<td>0</td>
<td>0%</td>
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</tr>
<tr>
<td>Math</td>
<td>0</td>
<td>0%</td>
<td>0%</td>
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<tr>
<td>Non-task talk</td>
<td>13</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td>Planning</td>
<td>12</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td>Total</td>
<td>477</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 5.4: Percentage of talk divided in categories.

<table>
<thead>
<tr>
<th>Category</th>
<th>Eva</th>
<th>Marianne</th>
<th>Manuela</th>
<th>Teacher</th>
<th>Student</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage</td>
<td>35%</td>
<td>35%</td>
<td>18%</td>
<td>11%</td>
<td>1%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 5.5: Individual talk in percentage of total talk
VI Ownership:
Eva has initiative to work process and do the practical work. The others do their windings as well but it is the motor Eva makes the one they use. Eva takes the leader's attitude and is quite demanding:
(8)
Eva: Think! Think!
She corrects the others for the improperly wound coil. Avoids talking about why the motor spins. Manuela backs off but she still keeps her own winding and finally tries when the chance comes.

VII Motivation
Effort:
(9)
Marianne: Listen!!! Isn’t it like this! It tries to get into equilibrium. But if we keep turning the current off and on all the time a force is induced. When we had this thing with the magnets and conductors it was…
Manuela: Yea, that’s right…
Manuela tests her winding. It wobbles as the axes are not symmetrical.

Persistence: They work intensely during a lab session and a video tape of 60 minutes could be analysed.

Energy put in during process:

<table>
<thead>
<tr>
<th>DURING</th>
<th>Physics</th>
<th>Percentage individual talk of physics talk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eva</td>
<td>143</td>
<td>44%</td>
</tr>
<tr>
<td>Marianne</td>
<td>55</td>
<td>17%</td>
</tr>
<tr>
<td>Manuela</td>
<td>72</td>
<td>22%</td>
</tr>
<tr>
<td>Teacher</td>
<td>53</td>
<td>16%</td>
</tr>
<tr>
<td>Student</td>
<td>5</td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td>328</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 5.6: Individual talk as percentage of physics talk during lab session.

<table>
<thead>
<tr>
<th>DURING</th>
<th>Concepts</th>
<th>Percentage individual talk of concepts talk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eva</td>
<td>7</td>
<td>8%</td>
</tr>
<tr>
<td>Marianne</td>
<td>81</td>
<td>92%</td>
</tr>
<tr>
<td>Manuela</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Teacher</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Student</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>88</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 5.7: Individual talk as percentage of concepts talk during lab session.

Outcome:

VIII Quality of work:
Amount of work
The quality in aspect of time spent on the task is high; in fact they talk about the task for 84% of the time during the lab session. They continue to work on the task as we
can see in the presentation that contains a whole part concerning voltage that was not discussed during lab session.

Development of competence

The group increase their holistic understanding by the new experience of how to build a model motor. The increase in conceptual understanding is not that high.

Eva: Yes, this one. The electric energy goes in and it is converted into kinetic energy. It is amazingly efficient; up to 90% of the electric energy can be converted into kinetic energy. Picture two please. ...The principle of an electric motor is one of having a conducting wire in coil that is supported by its axle - here is a drawing - or a picture; a motor construction looks like this...(shows the groups electric motor model.) The simplest motor that can be conceived of is, while rotating within a horseshoe magnet, of having a current go through a wire, which induces a magnetic field. The field from the wire and the field from the permanent magnet interact which result in a net force, which causes rotation. The part of our motor is shown in picture number ten.

Marianne: Here we have mounted our coil. It is suspended in the motor chamber. This coil is insulated so we trimmed the wire to enable contact on the other side there and on the underside here. Now we have contact - now no contact. Picture twelve please. Connect to a battery. Now we have a magnetic field there and a magnetic field from the wire. When it is trimmed of insulation and not trimmed - the pulsing induces the motor to spin.

Kenneth: Is the on/off action controlled by motion itself?

Marianne: Yes, actually it is the shifting of the poles from plus to minus where the battery is connected to the axle. After a half turn there is still motion but it would stop without pole reversal. Since the poles reverse it continues. I understood it as...the push it got was because of the trimming of the insulation and was enough to turn 180 degrees. Does it have enough to go more than that?

Kenneth: Oh. So if it wasn’t trimmed we would have had a constant direction for the electricity and it would have stood still.

Marianne: Yes, that’s right.

Margareta: I didn’t really understand what you were referring to the plus and minus?

In the discussion it became clear that Marianne was referring to a different motor with a commutator, which they had seen a good picture and schematic drawing of.

Manuela: As you can see we have a few pictures of different kinds of electric motors. Sewing machines, electric toothbrush... There are other motors such as diesel, gasoline. The main advantage with electric motors is that they are clean and quiet. The other kind of motor can release pollution and toxic fumes that contribute to the greenhouse effect. That in turn warms the earth. How does the electric motor affect us? There are electric motors everywhere. People used to be dependent on farm animals but can now use electric motors.

Development of self-confidence and self-esteem.

They are very satisfied with their results and express that to students visiting from a secondary school.

Eva: We thought we would talk about electric motors. We are the ones who are rather handy and thought it was fun to make motors.
**IX Quality of output:**

**Presentation:**

Shown here are small designs made by small children. A fan and light powered by a battery.

![Small designs](image1)

Fig.5.5: From the Electric Motor MP presentation.

Creativity=(new ideas) : YES; Amount of work (High, Medium, Low): Medium; Response from audience: YES; Lab activity: YES; Impression: GOOD; Time: 20 minutes;

<table>
<thead>
<tr>
<th>Presentation</th>
<th>Physics</th>
<th>Concepts</th>
<th>Planning</th>
<th>total talk</th>
<th>%talk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eva</td>
<td>82</td>
<td>109</td>
<td>70</td>
<td>261</td>
<td>38%</td>
</tr>
<tr>
<td>Marianne</td>
<td>49</td>
<td>180</td>
<td>0</td>
<td>229</td>
<td>33%</td>
</tr>
<tr>
<td>Manuela</td>
<td>144</td>
<td>0</td>
<td>0</td>
<td>144</td>
<td>21%</td>
</tr>
<tr>
<td>Teacher</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>13</td>
<td>2%</td>
</tr>
<tr>
<td>Student</td>
<td>38</td>
<td>0</td>
<td>0</td>
<td>38</td>
<td>6%</td>
</tr>
<tr>
<td><strong>326</strong></td>
<td><strong>289</strong></td>
<td><strong>70</strong></td>
<td><strong>685</strong></td>
<td><strong>100%</strong></td>
<td></td>
</tr>
</tbody>
</table>

% of all talk 48% 42% 10% 100%

Table 5.8: Amount of words in transcript of presentation(%).

**Products:**

Report: Their written report was a traditional lab report of ordinary quality. Amount of work: medium; Design: Good; PowerPoint presentation: Good Physics: Good; Creativity: Yes

**5.3.3 Summary**

Interest in physics

They find physics interesting because it is practical, useful and fun. They think it is of importance to have holistic understanding of the nature and of technology.
Interest in the MP
Eva focus early into this project, and the others join her. They value this MP high, as it is fruitful to them as future teachers. They also appreciate the connections to everyday life physics, and to the possibility to finally do this as women, they did never do it as girls.

Ownership given from the instructional design
As a group they immediately take the ownership when the design gives them this possibility. They do not search contact and help from the teacher, only when it come to the question of new batteries, and to get a check for the right answer on why the motor function at all.

Competence
The test showed different abilities an individual level. All three had test result with weakness in especially the holistic understanding. Marianne shows the strongest results, and Manuela showed low scores.

Communication
95% of all talk concern physics in the task. Eva is dominant (44%), and this is a consequence of her ownership to the task. Marianne (17%) and Manuela (22%) and the teacher (16%) share equal part of the rest of conversation. When they discuss the function of the motor they use exploratory talk, even if this is more used by Marianne and Manuela then by Eva. Eva drives the task by her initiative to all practical moments. She avoids the talk about why the motor rotate, but she checks with teacher to have a correct explanation before her part in the presentation. Marianne stands for all planning talk. We see this as a consequence more of her ability and competence in theory.

Motivation and ownership during work
As they talk physics all the time the motivation is high. The persistence is the 60 min lab session that is video-filmed, but they divided the rest of the work in different parts to make a rational home work for the presentation. By this their contributions to the presentation become quit different and personal. Manuela gave an impression to have low possibility to give her voice heard against Eva, but she takes a big part of the presentation. Her interesting show of electric machines that she has built together with her son, show her high motivation to the task. Also Marianne show high motivation by creative ideas about the motor function, and about her explanation of other electric motor models.

Development of competence
Manuela comes up with nice thoughts about science in society during the presentation, and shows models she has built with her children. Eva is practical and very familiar with how to use the instruments to measure current and voltage even without talking to the others about it. Marianne has prepared herself with reading about electric motors that are more advanced then this simple model, and has difficulties to recognise the different parts of the motor in practice. She shows some interesting mix of concepts from explanations to different phenomena. Her thinking of the electric motor rotating because of induced voltage when the coil get and lose contact with the battery was there also in the presentation, but this show an
engagement to try to understand that we saw as a sign learning in progress even if it was not correct in a scientific point of view.

Development of self-confidence and self-esteem
They succeed with their intentions to make the motor go around, and had a nice self-confident attitude at presentation, even if they were a bit unsure and had different views of why the motor did go around after all.

5.3.4 Discussions about evidence

<table>
<thead>
<tr>
<th>BEFORE PRIOR</th>
<th>Start of MP START</th>
<th>WORK PROCESS DURING</th>
<th>OUT – COME FINAL</th>
</tr>
</thead>
</table>

**INTEREST**

II in physics: useful fun practical difficult find need to make school physics interesting, to stimulate curiosity

III in MP:
fear of time-pressure if fruitful to future

RESULT IN TEST

IV Competence:
(formula calc, conceptual understanding, contextual understanding) Max(7,8,7):

**OWNERSHIP**

I Own at start:
Group level
Unique question based on their common need for practical knowledge in future (1)
They like to be together, as the three women that will go for teaching in secondary school, the others go for upper secondary school teaching.

Individual level:
Eva is very clear about that her practical experience as a welder, gives her an eye for technical issues. This gives her ownership to this task.

**MOTIVATION**

V Communication:
Use exploratory talks Use internal teaching
Content in group talk:
Physics related (95%), Equipment (0%), Math (0%)
Planning (3%), Non-task-talk (3%)
Individual talk:
Eva (35%)
Marianne (35%)
Manuela( 18%)
Teacher (11%)

VI More ownership:
Individual planning talk:
Eva (0)
Marianne (100%)
Manuela( 0)
Eva takes the initiative to all actions, but Marianne express what they should do.

VII “Motivation”:
Persistance: 60 minutes lab session on video-tape plus presentation at video-tape.
Efficient at school, and planned for at home, different parts

**COMPETENCE**

VI Quality of work
High amount of work (98% of all talk concern the task)
Development of: - understanding of physics:
Conceptual change Marianne develop her understanding about why the motor rotate, her thoughts are discussed in presentation - holistic understanding of physics:
Motor in history, motor as power for simple machines build with children (seen in presentation) -self-confidence by experience of own abilities and letdowns:
practical and theoretical difficulties -competence:Yes

IX Quality of out-put See text

Fig 5.6: The Electric motor group - model of related variables

Marianne are best in competence test, and will be the one that try to understand why the motor winding moves and the motor goes around. She contributes with 17% of the physics talk, but with 92% of the concepts talk, in fact she is a bit alone in trying to
discuss this question. She try to take this part in presentation as well, but mix it up a bit with an explanation of a more complicated motor model she found in a textbook. She has ownership as she like to work with "real-life" questions, but she let Eva take the initiative to practical laboratory work. She has individual ownership by her interest in the physics behind the motor as well as the interest in things used in "real-life". She show motivation by her high contribution to concepts talk (92%), and to physics talks (17%). Her development of conceptual understanding are seen in the presentation, where she try to give an explanation to why the motor go around, and also defend her view in discussion with a fellow student that challenge her. This we see as a sign of both conceptual understanding and as a sign of increased self confidence and self-esteem.

<table>
<thead>
<tr>
<th>The causal relation for Marianne:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Interest</strong> in physics, found it fun in school. Finds it important to be able to talk physics and discuss, not only make formula calculations. Has no experience of to build a motor, but like to take this chance now.</td>
</tr>
<tr>
<td>→ <strong>Ownership by the choice of a MP:</strong></td>
</tr>
<tr>
<td>Likes to do something from &quot;real life&quot;.</td>
</tr>
<tr>
<td>→ <strong>Motivation:</strong></td>
</tr>
<tr>
<td>- high competence in test.</td>
</tr>
<tr>
<td>- takes 35% of all talk during lab session, and all planning talk.</td>
</tr>
<tr>
<td>- communicates in exploratory talks especially with Manuela</td>
</tr>
<tr>
<td>- Does the theory part of the presentation.</td>
</tr>
<tr>
<td>→ <strong>Competence</strong> Searches for learning by exploratory talks about why the winding moves. Does not reach all the way to a scientific view, but deepen her understanding about magnetic field and forces.</td>
</tr>
</tbody>
</table>

Manuela has low competence in test. She contributes with 22% of the physics talk, but with only little conceptual talk. But she come into exploratory talk with Marianne and improves her conceptual understanding by expressing her thoughts. (#(6))

Manuela: And why does it spin? It must be the magnetic field…
Manianne: It has to align itself with the magnetic field…
Manuela: The current goes this way and the magnetic field goes this way…it is influenced by a force.

Manuela has individual ownership by her interest in the MP, and by her wish to find fruitful knowledge of practical work to use as a teacher. She has also high motivation seen by her initiative to use the electric motors in simple machines as she uses in the presentation. She develops her conceptual understanding (#(6)) and her holistic understanding of electric motors in society and history (#(12)).
The causal relation for Manuela:

**Interest** in the MP, find it interesting and fruitful. No earlier experience of electric motor models

→

**Ownership by the choice of a MP:**
Like to work with practical tasks that could be used in the future as a teacher. Some ownership to this task.

→

**Motivation:**
- low competence in test
- Low possibility to initiative by the dominance of Eva to practical work. Do not give up this, wait with patient and try her own windings at the end. This is a sign of motivation. Take 18% of all talk during the laboratory session, but 22% of physics talk. No contribution to concepts talk.

→

**Competence** as development of holistic understanding: Build electric machines together with her son. Give history of the motor in society. Some signs of development of conceptual understanding during exploratory talks with Marianne.

Eva has earlier experience of practical work also with electric equipment as a welder. She has high individual ownership to the task. She likes to find practical tasks to use as a teacher in future. She likes to build the electric motor model, and what is really important is that it works, but not that important to explain why and how (only 8% of concepts talk).

She has motivation, we see that by her contribution of 35% of total talk and 44% of physics talk, and by the fact that she do almost all practical work during lab day. In presentation she confirm her attitude by her presentation:

(#13)

We are the ones who are rather handy and thought it was fun to make motors.

The causal relation for Eva:

**Interest** in holistic perspective and in MP and has **experience** of practical work with electric equipment

→

**Ownership by the choice of a MP:**
- likes practical work
- finds the MP useful as a future teacher
- informal leader in the group

→

**Motivation:**
- medium test result, but very qualified in practical laboratory work
- high contribution to physics talk

→

**Competence** as development of holistic understanding: In presentation she talks about the history of motors, (also steam-engine) and compare their history. She also gives an explanation of why the motors go around, and that we see as a sign of development of conceptual understanding. Her self esteem and self-confidence are shown by a secure and safe part of the presentation.
Chapter 6     MP at Upper Secondary school
6.1     Overview of MP at Upper Secondary school
At the start the students 1) discussed in groups a list of 20 proposed MPs including number one, a totally free choice. They were then 2) asked to individually grade the MPs with respect to how motivated they felt to choose a specific MP. Motivation was then described for the students as their interest, curiosity, joy, usefulness and security to succeed. They graded the miniprojects in a Likert scale from 1 to 6 where 1 stands for “No, very little” to 6: “Yes, very much”. Finally 3) they made an individual choice of MP to work with.

Fig.6.1: How 15 students aged 17 ranked 20 different MPs sorted in categories: 1 Own choice 2 Natural phenomena 3 Verification and calculations, 4 Technical applications, 5 Maths problem solving in physics 6 Physics concepts 7 To teach others 8 CRP

As a group the students preferred specific miniprojects but the tendency towards a particular category is not that strong, even though all MPs from the category Technical applications two projects are ranked rather high compared to the others. They ranked as number one with average 5.6 “The Electric Motor. Make a model and explain how it works.” From the category natural phenomena was number two “The Thunder – a phenomena in the electric field around the Planet earth. Illustrate and explain thunder and lightning.” with 4.6. Number three was from Technical applications again “Make a strong electromagnet and determine its lifting force.”

The tendency is to choose tasks that are not mathematical but are fun, practical and with the power to give brief understanding of phenomena beyond technical and natural phenomena. Compared to the teacher the students are not that interested in verification of Coulomb’s Law (only 2.3), which was the teacher's highest priority (6).
And the students do not prefer to make a project of their own in this context (2.0). The two CRPs that were given in this context were ranked low. In the situation of reading all 20 MPs, they seemed to be too complicated to get into quickly.

![The Physics teacher's ranking of the 20 MP](image)

Fig.6.2: How the physics teacher in class ranked the MP from his point of view.
1 Own choice 2 Natural phenomena 3 Verification and calculations, 4 Technical applications, 5 Maths problem solving in physics 6 Physics concepts 7 To teach others 8 CRP

### 6.2 Case 3 – MP To teach electric circuits to other students.

#### 6.2.1 Overview of case 3

**PRIOR:**
The four girls here called Ann, Lena, Kathy and Kristin are 17 years old and study together the physics course in the Natural Science program. They have known each other over the years they have spent together in secondary school. They have found physics in school boring and demanding, but they are successful and have a positive attitude towards school work. They choose as MP to teach electric circuits to younger students. The MP is formulated:

**Explain and demonstrate by example electric series and parallel circuits for a secondary school class. Make plans for this and show your experiments.**

They like to repeat and understand what they do in physic so they find that this MP suits them.

**DURING:**
The four girls start to plan their MP. The time line for the session shows that the main thread is to discuss and understand the analogy they have learned in secondary school about “crocodiles as resistance”, and to plan the presentation and start to practise for the presentation.

**Time-line:**
- min 0-3 They make plans for work and start to specify the task.
- min 3-10 What theory do they have? How to change resistance and why?
min 10 - 19 A rough plan for what they will include in their presentation.
min 19 - 29 Start to collect equipment to build electric circuits.
min 30 - 38 Build the circuits and discuss them
min 39 - 44 Take photos of their circuits
min 44 - 53 Plan for the presentation, revise what to do.
min 54 - 61 Explain resistance to each other with the “crocodile” analogy
min 62 - 66 Make drawings on black board, explain and discuss
min 67 - 72 Questioning the strategy. Discuss advantages and disadvantages.
min 73 - 82 They change the strategy and make new plans.

OUTCOME:
They fulfil their task and make a qualified presentation and a correct report of their work. In the presentation they modify their view of “crocodiles as resistance”, and show signs of conceptual change.

6.2.2 Results
Prior:
I Ownership at start:
They choose a content that contains a unique question.
Three of the girls have heard the same funny explanation of current and resistance in secondary school. They want to choose the MP to teach others electric circuits based on this common experience, which gives this group a unique question, but as they find the task interesting they worry that maybe other groups will choose it as well. They think it is a secure way of doing this task. Ann and Kristin are very interested. Kathy does not comment on this. Lena is worried about how to explain this.

(1)
Anna: Then you can compare to water and tubes and how much goes through – resistance and all that...
Anna: I think it will be fun. You have to think for yourself and than you will understand yourself too.
Kathy: It is a basic thing to do.
Lena: But it is difficult to explain...
Anna: But it still is more fun...maybe all the others would like to do it too so we have that problem?

Performance and presentation are free choice
The group are free to choose how to perform the task. A high degree of ownership given by this instructional design. They choose to focus on a teaching sequence, they think of explaining for younger students how to understand the concepts of resistance and current in electric circuits. They take for granted that their presentation will be invented, that they will do their presentation in front of their own class to their own peers. They could have chosen to go into another class to fulfil their presentation but they did not.

They choose the kind of results they will go for.
They also have a high degree of ownership in deciding what kind of results they try to reach. They negotiate about this:
(2)
Anna: We might need to explain what an electron is too.
Lena: Boys and girls are positive and negative charges that are trying to get to each other.
Ann: What is a charge?
Kristin: MARGARETA!? We must ask how much the elementary class knows.
Lena: We should probably not go deeper that this.
Anna: It should not be too shallow either.
Lena: This is a perfect introduction.

The individual choice of MP versus the final group choice of MP.
Kristin has high ownership of the choice of the MP. She states the reasons for choosing this MP and convinces the others that this is a secure and useful MP. Ann backs Kristin up and agrees with her arguments of security and usefulness. For Kathy it is of importance to choose an MP that keeps the group together, she is afraid of coming in the same group as Johan who she finds arrogant and who she is in fear of.

3)
Kristin: To be on the safe side we should probably take up things that don’t belong to the B-course. It would be…18 seems like fun. Yes, that one would be fun.
Anna: One needs to explain to an elementary school class so that they understand and that means we need…
Lena: Yes, we’ll take that one.
Anna: Yes, 18 was good.
Kathy: Right…I don’t want to be with Johan and the others…they are just too clever.
Anna: It is a good thing if somebody is good at it…
Kristin: It feels like he thinks one is stupid…I don’t feel like working with Jonas and the others. It makes me feel dumb; they can work with themselves.

and later
Kristin: I like 18. I love that kind, well, not love but…To be able to explain what one does, that is really important. I don’t just want to learn, I want a deep understanding. Like today in math…

When they finally give their individual choice they all give the reasons useful to revise, fun to see if one they can explain to others, nice to think of physics from a different perspective:
(4)
Anna: This MP seems to be most fun. I find it interesting to see if I can give a good explanation in an easy way. It is good for me to revise the basic principles again.

II Interest in physics:
The students start to discuss expectations of work with miniprojects. They say that they find their physics lessons in gymnasium so far have included theory and laboratory work in an endless process that is difficult and boring. They hope that this will be fun and that there will be something to choose that they are able to understand.
(5)
Kathy: I think anyhow it will be nice to do something of another kind.
Kristin: It is different to theory -lab work.
Lena: Yes, that is boring.
Anna: Tell them louder…
All girls: Physics is boring!!!
Kristin: So it would be fun if this was fun, I mean…it (physics) is often so difficult it can’t be done!
Anna: If we find something we are able to do … at least…

They say about physics in school that it is difficult to understand what it is all about:
(6)
Kristin: But in upper secondary school, you have only boring subjects
Anna: Yes, physics in particular, it was so difficult in the beginning...
Kristin: Yes, you didn’t understand anything, that’s why. We hadn’t done optics before, I did not even know the word.

They point out explicitly the importance of understanding what it is all about and the connection to something useful, not only to make abstract calculations. They find the physics concepts of voltage and potential strange.

(7)
Kristin: In fact it would be best to do something you understand. Something of this kind...
Lena: Yes, something you understand.
Kristin: Something you can see. So you can understand it immediately, it will be like this...
Something that is useful and interesting. How fun is it to do calculations on voltage and potential differences, you don’t even see those odd things.

III Interest in MP:
They try to find some specific MP interesting, but they only find a few and it is not easy to find one of your own:

(8)
Lena: We are supposed to give proposals for our own MP.
Anna: I have no suggestions.
Lena: We have to look at that first- our own ideas.
---
Kathy: No 9...
Kristin: That one is not that much fun...
Lena: Make an electric motor and explain how it works - that sounds fun!
Anna: Make a demonstration of a transformer and transform current and voltage.
Kathy: But what is a transformer?

They soon agree of a favourite, the MP that consists of making a demonstration and explanation of series- and parallel electric circuits for younger children. The reason for this is security. They find they understand these themselves and that it will give them even deeper understanding after they have done this project. But they consider the choice carefully:

(9)
Lena: It could be difficult to explain to them.
Kathy: Does it have to be that easy?
Lena: What did you say? No, but it is difficult isn’t it? Can you explain to me?
Kristin: A parallel circuits or the differences or..?
Lena: Well, how the current moves..?
Kristin: Yes, in a parallel circuit ...or..well, in a series circuit, the light become weaker and in a parallel electric circuit the light will be the same and...
Anna: Then you can compare to water and tubes and how much that goes through – resistance and all that....
Anna: I think it will be fun. You have to think for yourself and than you will understand it yourself too.
Kristin: It is a basic thing to do.
Lena: But it is difficult to explain...
Anna: But it still is more fun...maybe all the others would like to do it too so we have that problem?

IV Competence:
The physics test with five questions in formula calculations, five in conceptual understanding, and five in holistic understanding could give maximum (5,5,5) points.
The four girls got: Ann (4,1,4) Lena (4,3,4) Kathy (4,2,5) and Kristin (2,2,5). They are all strong in holistic understanding but not that good in conceptual understanding. This could be an effect of the teaching in secondary school.

During:

**V Communication**:

Exploratory talks
They show examples of exploratory talks when they try to agree on what they really mean with the analogy about current as boys and girls and resistance as crocodiles in the electric circuits:

(10)

Lena: The crocodiles like to eat people so every now and then some disappear. That is what the resistance is, the things that stops the current.
Kathy: If one has a circuit connected in series and there are two wires for every light bulb would the lights be equally bright?
Lena: Yes, (unsure), it should be…?
Kristin: If you have two wires?
Anna: No, but one usually says that the wires are without resistance. It is the light bulbs that have the resistance.
Lena: Do you understand this now or should I explain a little more?
Kristin: Parallel circuits…
Anna: Is this just for current and resistance?
Kristin: If you have two bridges is it not easier to get across?
Anna: What are the crocodiles again?
Lena: Resistance.
Anna: And small bridges are also resistance?
Lena: Yes, and the people are the current.

Another example.

(11)

Kristin: The current in this one has two choices. Unlike this one (pointing to a series circuit with two lights) which has only one way to go…That is why they are equally bright. But why do they shine equally bright?
Anna: Because the current divides itself equally in half.
Lena: But I think that is so weird. If it is divided there is only half for each one. Then it is divided again there but still we see that it isn’t that way…

**Internal teaching**

Lena has the initiative in telling the others about this analogy. She teaches the others:

(12)

Lena: There are three terms. Voltage, current and resistance.
Anna: That can be written on the whiteboard as V.I.R. for short.
Lena: Voltage, or electric potential, does not need to be discussed now. However, resistance and current need to be explained. Imagine a river, (drawing on the whiteboard), and on this side we have girls and on the other side we have boys.
Communication content:

Table 6.1: Amount of talk divided in categories (%).

<table>
<thead>
<tr>
<th>Category</th>
<th>% of total talk</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of total talk</td>
<td>Ann 37%</td>
</tr>
<tr>
<td></td>
<td>Lena 29%</td>
</tr>
<tr>
<td></td>
<td>Kathy 11%</td>
</tr>
<tr>
<td></td>
<td>Kristin 21%</td>
</tr>
<tr>
<td></td>
<td>Teacher 2%</td>
</tr>
<tr>
<td></td>
<td>Total 100%</td>
</tr>
</tbody>
</table>

Table 6.2: Amount of total talk divided into individuals(%).

### VI Ownership:

Planning talk divided by person

<table>
<thead>
<tr>
<th>Person</th>
<th>% of total talk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ann</td>
<td>36 46%</td>
</tr>
<tr>
<td>Lena</td>
<td>24 31%</td>
</tr>
<tr>
<td>Kathy</td>
<td>4 5%</td>
</tr>
<tr>
<td>Kristin</td>
<td>14 18%</td>
</tr>
<tr>
<td>Teachers</td>
<td>0 0%</td>
</tr>
<tr>
<td>Total</td>
<td>78 100%</td>
</tr>
</tbody>
</table>

Table 6.3: Amount of talk marks for planning (%).

Lena, Ann and Kathy carry the lab equipment but Kathy waits for them sitting at their table. We see this as a sign of low ownership compared to the others. They all take part in the activities with enthusiasm but Kathy is not as active as the others in planning what to do next (5%, compared to Ann 46% and Lena 31%). Lena, Ann and Kristin rehearse the presentation at the blackboard. Kristin changes the strategy with her suggestion that in the presentation two of them should act as younger students. She will act as a school teacher. They negotiate over this, this also can be seen as an act of negotiation about ownership of activity.

### VII Motivation

Energy put in during process

Percentage of physics and conceptual talk divided on person shows that Anna (26%) and Lena (33%) are dominant in physics talk but Kathy (17%) and Kristin (17%) are included in the discussions about the explanations as well but not that much. In talk about planning Anna (46%) and Lena (31%) were dominant too and the contribution from Kathy (5%) quite low but Kristin (18%) was active and showed initiative and
creativity. The amount of disturbance in form of talking with a non-MP content was as low as 16%, and the energy put in is high.

Physics and conceptual talk divided on person

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ann</td>
<td>14</td>
<td>26%</td>
</tr>
<tr>
<td>Lena</td>
<td>18</td>
<td>33%</td>
</tr>
<tr>
<td>Kathy</td>
<td>9</td>
<td>17%</td>
</tr>
<tr>
<td>Kristin</td>
<td>9</td>
<td>17%</td>
</tr>
<tr>
<td>Teachers</td>
<td>4</td>
<td>7%</td>
</tr>
<tr>
<td>Total</td>
<td>54</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 6.4: Physics and conceptual talk divided into individuals (%).

Achievement
The group fulfil their ambition to make the design for the teaching sequence, to choose and carry through the laboratory work to connect series and parallel circuits and they spend a lot of effort in reaching consensus about how to explain current and resistance. They also find their analogy about crocodiles as resistance inadequate and show signs of development of their conceptual understanding.

Outcome:
VIII Quality of work:
Amount of work
The quality in respect of time spent on the task is high; in fact they talk about the task 84% of the time during the lab session. They continue to work on the task at home. We can see in the presentation the content of a whole part concerning Voltage that was not discussed during lab session.

Development of competence
During the lab session the students' own views of what current is, what resistance is and how series and parallel circuits function is challenged by the others all the time. They use exploratory talk in long sequences when they feel that they soon will grasp how it really functions. Lena who found this hard to explain in the first place together with Ann makes a conceptual change from current as consumed by resistance (the crocodiles) to a view that resistance changes the speed of the current, that means fewer electrons per second through the lamps in a series circuit compared to the parallel circuit. This development had a relieving effect on the group, and the spirits ran high.

(13)
Kristin: But what can I say about series circuits?
Lena: It is the Christmas lights.
Kristin: Yes…if one of them goes out, the rest of them go out too. Like the Christmas tree lights…and here are the parallel circuits…the current has two paths to chose from…and then it divides itself up and just as much current goes there as there and then the two lights shine equally bright.
Anna: …equally bright. ..
Kristin: ..equally bright, instead of two that are dim. (pointing to the series circuit.
Anna: Don’t they shine with different intensities in the series circuit?
Lena: I kind of think they should…
Anna: …the last one should be less bright than the others, but maybe it doesn’t?
Kristin: No, they are equally bright.
Lena: That is because there are crocodiles in the way and it is hard for them to get by.
Kristin: So if we had a parallel circuit series...
Lena: Wait a second...with resistance...they don't get eaten up, it is because the current goes fast.
Anna: ...it slows down...
Lena: ...if the current goes fast the lights are bright and if the current is slow the lights are dim...
Anna: It depends on how many electrons go through. The resistance is what causes fewer electrons to go through the lights.
Lena: ...per second, it slows the speed.
Anna: Yes, that right, it goes slower, they are not being eaten...
Lena: ...that is the reason a light in a series circuit is dimmer, it is slower...
Kristin: Should we divide ourselves up? And pretend to be 7th graders?
Anna: ...the one who asks questions all the time is....
Lena: ...this is really great..
Lena: ...now I actually understand series circuit...it is the first time!!
Kristin: Lets do this and pretend that we are having a lesson.
Anna: Yes, that would be better…
Kristin: Is that what we will do? How fun! I want to be the teacher. We can ask if we can do that. MARGARETA!

Development of self-confidence and self-esteem
The students negotiate over control and initiative of the project progress. Kristin was out for 10 minutes and during that time Ann, Lena and Kathy made a disposition for the presentation. When she comes back they are already rehearsing for the presentation:
(14)
Kristin: But what will I say?
Anna: But that is what I am saying! I too want it written down, right now only Lena is talking.
I think it is easier if we sit down and write everything that has been said.
Anna: ... and Kristin has not been with us from the start. (Kristin left earlier)
Lena: Should we start over from the beginning?
Kristin: All the restroom doors were locked; I went all over the place. Yes.

After a while Lena and Ann have had a long discussion of resistance and Kristin takes the opportunity to take back her initiative with a good new idea:
(15)
Kristin: Can’t we divide ourselves up and pretend to be 7th graders?
Anna: The one who asks lots of questions is…
Lena: ... that’s great…

IX Quality of output:
Presentation:
The presentation includes a nice piece of physics which also shows the conceptual change concerning resistance from consuming charges to slowing down current.
(16)
Lena: I want all of you to pretend that you don’t know much. (Starts to draw a circuit with to light bulbs) Now, imagine one of these (points to a voltage regulator and a battery symbol in the drawing) And then imagine a light there and there. Now a current will go through the circuit. When I explain what current and resistance are I will use a picture -here is a bridge...I will make use of a river and a bridge. Do you see what I am drawing? This is a river and this is a bridge. So there are boys here (pointing) and girls there (pointing). The boys want to get to the girls and girls want to get to the boys. So the girls run here (pointing) and the boys run here (pointing). But there is a problem, the bridge is kind of narrow even though it does not show in the picture, and they can’t cross very fast. That
slows down the current. Then there are the crocodiles (pointing) they look dangerous. Every now and then some of the boys and girls fall in and the crocodiles eat them. That also slows down the current. So the current is the boys and girls and the resistance is the crocodiles and the narrowness of the bridge, in other word the stuff that slows them down. And now I have come to the voltage. One can think of voltage as a waterfall…water runs like this…really fast and churning…down there.

Lena: ...Wheels here…which represent the light bulbs. When the water falls from a high place, the wheels turn and the lights go on.

Fig. 6.3: The analogy with the crocodiles.

Fig.6.4: Lena draws a picture of a waterfall including a paddle wheel as an analogy to a bulb in a electric circuit.

Fig.6.5: Lena draws a picture of a waterfall including a paddle wheel as an analogy to two bulbs in a series circuit.

Lena: When the water falls from a high place the light work…yes…If one thinks of the lights in a series circuit…they must…the current goes through the one first and the other second. There…and now we have half the height we had before which makes the lights less bright. So with a series circuit the lights will be dim.

They also have included the voltage concept into the presentation and all girls use it in their three different circuits.

Kristin: Here is a parallel circuit. It looks like this. (Draws)

Fig.6.6: Kristin explains parallel circuits as bulbs with same height of fall in the waterfall.
Kristin: Both wheels will spin and they have the same falling distance. When you have parallel circuits the current divides here and then the wheels turn and the light go on. The wheels will spin equally fast because the falling distance is the same for both...here is where a parallel circuit is stronger...as opposed to a series circuit that shares the falling distance.

All girls are active during presentation.

Kathy: This one gets all the current and the other one divides it up. There is a light there and two that are in series there. And the series circuit...the bad thing about series circuits is that if one part goes out everything goes out. Can we show them that? (shows it) It is commonly used in Christmas tree lights. Parallel circuits are used in the schools lighting system. The good thing about it is that less wire is needed.

![Parallel Circuit Diagram](image1)

Fig.6.7: Kathy shows her electric circuits on the white-board.

Kathy and Kristin do most experimental work, especially Kathy who is very good at it. Anna who is strong in theory and maybe not as fond of the crocodile analogy as the others, presents Ohm's law:

Anna: One can easily show the relationship between voltage, current, and resistance with the equation $V=IR$. This can be rearranged to $I = V/R$.

The response from audience is high. A contribution to their ownership is the acknowledgment from teacher who tells us that this model of the waterfall and its implication for circuits give him new insights how to explain the fact that there is a limit to how much current the could flow from the power supply to the circuits:

Teacher: For many years I have wondered about the waterfall thing, but now Lena has both explained and shown it to me. She drew a waterfall. One can have a large dam behind a waterfall...there are canals...and then the dam gets filled up by a river...When one connects lights in parallel it is like opening a new canal. Now we have this here...that depends on how much water there is in the dam. Considering the drawing on the board (draws a dam)

![Waterfall Diagram](image2)

Fig.6.8: The Teacher's drawing.

Teacher: Are there limits to how much current one get? Can one connect an unlimited amount of lights?
Student: Eventually more water would leave the dam than is going in...
Teacher: So that means there is a limiting factor. Are there other limiting factors? What could they be?

Creativity= (new ideas): YES; Amount of work (High, Medium, Low): HIGH
Response from audience: YES; Lab activity: YES; Impression: VERY GOOD; Time: 20 minutes
Table 6.5: Amount of total talk in presentation (%).

<table>
<thead>
<tr>
<th></th>
<th>Anna</th>
<th>Lena</th>
<th>Kathy</th>
<th>Kristin</th>
<th>Teacher</th>
<th>Margareta</th>
<th>Student</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>65</td>
<td>375</td>
<td>102</td>
<td>78</td>
<td>104</td>
<td>39</td>
<td>12</td>
<td>775</td>
</tr>
<tr>
<td>8%</td>
<td>48%</td>
<td>13%</td>
<td>10%</td>
<td>13%</td>
<td>5%</td>
<td>2%</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

**Products:**
- Report: Their written report was a traditional lab report of ordinary quality;
- Amount of work: medium; Design: Good; Power Point presentation: grade (VG, G);
- Physics: Good; Creativity: No;

**6.2.3 Summary**

**Interest in physics**
Students find physics interesting but it is made boring because of the time pressure and lack of possibilities for reflection and deepening of understanding. They also find the physics problems they do for exercises to be abstract and strange. They long for more familiar questions that are more clear and obvious to them. They also need more repetition and feel that they manage to solve the problems or have a chance to understand what it is all about. They say that school makes great demands upon them.

**Interest in the MP**
Students find MPs interesting if they understand from the beginning the purpose and meaning of the task. They do not like it to be too specified. The degree of freedom could optimally be 2, by that we mean the task can be formulated but not including instructions that are too specific. To be sure of success is important.

**Ownership given from the instructional design**
The possibility to decide content, question, performance, presentation and results are given to the group. They choose an MP that gives them a unique question and it is based on their common experience of the teaching of electric circuits at secondary school and especially the experience that three of the four girls share the analogy of crocodiles as resistance. This gives the group a high level of ownership of the MP. They discuss the risk to turning out unsuccessful and find a strategy for performance.

**Competence**
The girls are among the upper part of the class in physics tests and are ambitious in school. They are equally competent concerning grades in physics. In their first examination for the course Lena was one of the best in class, in fact one of two that took a “VG”, in the scale IG (unqualified), G (qualified), VG (well qualified), and MVG (very well qualified). In class in total the result was 1 IG, 12 G, 1 VG, 0 MVG. In test 3 of 4 showed good capability in formula calculations, all four showed weakness in conceptual understanding, and 3 of 4 were good at contextual understanding.
Communication

We film the group during the laboratory session for 80 minutes. The transcription shows that they talk about the task for 84% of the time and about pure physics for 29%. The need for talking about next steps and planning for the task takes 42% of the talk. They use exploratory talks to reach understanding. In fact they get much exited over the issue to find a plausible explanation for current and resistance and discover that their old analogy about crocodiles consuming charges has to be incorrect. This is no problem for Kristin, who believes what she sees; the bulbs are equally bright in all parts of the series circuits. She finally gets involved in the discussion when she has to do part of the explanation herself in presentation.

Motivation

The group shows persistence with the task. They use all the time during lab sessions and lots amounts of time at home to prepare for the presentation as it changes and grows from their plans during lab day, they finish the task with good results. The effort they put into the MP here shows itself as communication in exploratory talks, and in how they spend a lot of time to reach consensus of concept descriptions.

6.2.4 Discussion about evidence

<table>
<thead>
<tr>
<th>BEFORE</th>
<th>START</th>
<th>DURING</th>
<th>FINAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTEREST</td>
<td>OWNERSHIP</td>
<td>MOTIVATION</td>
<td>COMPETENCE</td>
</tr>
<tr>
<td>II in physics:</td>
<td>I Own in setting:</td>
<td>V Communication:</td>
<td>VII Quality of work</td>
</tr>
<tr>
<td>if reflective</td>
<td>Unique question based on their common experience</td>
<td>Use exploratory talks (10)</td>
<td>High amount of work</td>
</tr>
<tr>
<td>(picture)</td>
<td>(1)</td>
<td>Use internal teaching (11)</td>
<td>(84% of all talk concern the task)</td>
</tr>
<tr>
<td>if understandable</td>
<td>Talk about the proposed results and the risks in MP</td>
<td>Content in group talk:</td>
<td>Development of:</td>
</tr>
<tr>
<td>(5),(6),(7)</td>
<td>(2),(3),(9)</td>
<td>Physics related (29%),</td>
<td>- understanding of physics:</td>
</tr>
<tr>
<td>III in MP:</td>
<td>Talk about performance (9),(10)</td>
<td>Equipment (12%), Math (2%)</td>
<td>conceptual change</td>
</tr>
<tr>
<td>nice with</td>
<td></td>
<td>Planning (42%), Non-task-talk</td>
<td>(14), (17)</td>
</tr>
<tr>
<td>variation (5)</td>
<td></td>
<td>(16%)</td>
<td>- holistic</td>
</tr>
<tr>
<td>to explain and</td>
<td></td>
<td>Individual talk:</td>
<td>understanding of</td>
</tr>
<tr>
<td>repeat (4)</td>
<td></td>
<td>Anna (37%), Lena (29%),</td>
<td>physics (17)</td>
</tr>
<tr>
<td>not easy to</td>
<td></td>
<td>Kathy (11%), Kristin (21%)</td>
<td>-self-confidence by</td>
</tr>
<tr>
<td>suggest physics</td>
<td></td>
<td>Teacher (2%)</td>
<td>experience of own</td>
</tr>
<tr>
<td>MP (8)</td>
<td></td>
<td></td>
<td>abilities and letdowns</td>
</tr>
<tr>
<td>RESULT IN</td>
<td></td>
<td>VI More ownership:</td>
<td>(18)</td>
</tr>
<tr>
<td>TEST</td>
<td></td>
<td>Individual planning talk:</td>
<td>competence by</td>
</tr>
<tr>
<td>IV Competence:</td>
<td></td>
<td>Anna (46%), Lena (31%),</td>
<td>communication</td>
</tr>
<tr>
<td>(formula calc,</td>
<td></td>
<td>Kathy (4%), Kristin (14%)</td>
<td>training</td>
</tr>
<tr>
<td>conceptual</td>
<td></td>
<td>Kristin take more ownership</td>
<td>(1-18)</td>
</tr>
<tr>
<td>understanding,</td>
<td></td>
<td>(13),(14),(15)</td>
<td></td>
</tr>
<tr>
<td>contextual</td>
<td></td>
<td></td>
<td>IX Quality of</td>
</tr>
<tr>
<td>understanding)</td>
<td></td>
<td></td>
<td>out-put. See text</td>
</tr>
<tr>
<td>Anna (4,1,4,)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lena (4,3,4)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kathy (4,2,5)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kristin (2,2,5)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(good, weak,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>strong)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig.6.9: Summary MP Electric circuits. (Inside bracket reference to quotes in text)
When we put the variables into a more general model they fit into a causal relation not yet fully understood but with implications towards the impact from interest → ownership → motivation → competence.

**Anna** has a positive attitude towards school but finds physics difficult but she has been successful so far with good results in earlier physics tests. Anna likes to repeat, and finds the MP interesting.

(4)
Anna: This MP seems to be most fun. I find it interesting to see if I can give a good explanation in an easy way. It is good for me to revise the basic principles.

Anna finds this MP secure by that means that she will manage to solve the task and she finds it useful as she will get a possibility to think and understand when she explains it to others.(1)

Anna: Then you can compare to water and tubes and how much goes through – resistance and all that....
Anna: I think it will be fun. You have to think for yourself and then you will understand it yourself too.

She discusses the level of results they will go for and we see that as a sign of ownership.(4)

Lena: One should probably not go any deeper than this.
Anna: **It should not be too shallow either.**
Lena: This is perfect for the introduction.

She has experience of this analogy herself and this gives her ownership of the content area and of the question. Her contribution to planning is very high (46%), in fact she leads the project. This high motivation can be a result of her ability and her ownership. She also contributes to the development the physics understanding by asking the others questions that force them into exploratory talks. We see this as motivation as well. She talks in 37% of the total amount of talk during work but she takes only 8% of the talk during presentation which is a consequence of Lena’s high motivation to do the presentation.

She has high ownership of the content and question, a high motivation during work and high contribution to the quality of the presentation. She is involved in the conceptual change that is seen most clearly in Lena but probably goes for Anna as well.

(10)
Kristin: If you have two bridges is should be easier to get across right?
Anna: What are the crocodiles again?
Lena: Resistance.
Anna: And the narrow bridges are also resistance?
Lena: Yes, and the people represent current.
The causal relation for Anna:

**Anna** shows **Interest** in explaining phenomena and **experience** of the situation by explaining electric circuits

→

**Ownership of the choice of an MP that will allow**
- her repeat a piece of physics she finds useful,
- and to deepen her understanding by practising explaining to others.

→

**Motivation** is seen as
- her interactions in exploratory talks, she in fact provokes the others into it
- her high amount of total talk (37%), physics talk (26%) and planning talk (46%) during work.
- her special actions by provoking the others to do more and by challenging their understanding
- her amount of work in the product (High).

→

**Competence for Anna** is seen as
- her conceptual change to see resistance at the start as a consumption of charges into a view of resistance as decreasing current by decreasing current speed (amount of charges/time through a cross section of the wire). This is an increased conceptual understanding she shares together with Lena
- her management of the project gave her training in leadership as she was dominant in planning and initiatives during the whole process.
- her unobtrusive way in the presentation did not reflect her strong position during work, maybe this was another of her strong sides; to let others do what they do well.

**Lena** finds physics boring and difficult and longs for time for reflection as she answered at the initial questions.

Boooooring. Often rather difficult as well. Many parts are interesting if you have time to think of it but that time does not exist. It is all about understanding as fast as possible and then reading it for the test, and then to move on.

She is very interested in explaining and eager to understand physics phenomena. This we see as something that gives her ownership of the MP from the start; it is clear that this is what the MP is about, to explain and to understand current, resistance and voltage.

Lena: Yes, something you understand.

As she has interest in reflections over physics phenomena this MP gives her an opportunity to realise learning, this is what we see as having ownership. She is doubtful about how to explain resistance and current. She sees an anomaly in her own view of these concepts and expresses this to the others.

Lena: It could be difficult to explain to them.
Kathy: Does it have to be that easy?
Lena: What did you say? No, but it is difficult isn’t it? Can you explain to me?
Her ownership gives her motivation. A sign of motivation is her high contribution to planning talk, at the start seen as an ownership during work process (31%). Her high competence is also included there. Another sign of motivation is her high contribution to the amount of physics talk (33% of all physics talk). Her strategy is to try to explain to others and thereby show the anomalies and she thereby gets into exploratory talks. We see exploratory talks as a sign of motivation, a real effort to reach understanding.

Anna: That’s because the current sort of divides itself in half.
Lena: But I think that is weird. If it divides itself in half there is only half left. And it divides itself there too. But that is not what happens.

Lena is the one who does a lot of the presentation and a lot of the work to find a coherent explanation of current and resistance. (Some of her ownership of the content and issue was seen in their CRP that concerned their understanding of current and resistance as well.) As voltage is added into the presentation a lot of work has been done at home too, so the group did a lot of work before their presentation. She inspired the teacher during presentation by her analogies of potential differences as different heights but also different parts of the water quantity in the waterfall.

Teacher: For many years I have thought about the waterfall analogy and now Lena has both explained and illustrated it to me.

This acknowledgement of her ability to explain is a sign of her development of competence during this MP task, partly her own conceptual change and partly her increase in self-esteem and self-confidence and social competence.

The causal relation for Lena:

**Interest** can be seen from her interest in explaining phenomena and that she finds opportunities to reflect that were missing in school physics

**Her experience** of an analogy of resistance as an anomaly, she is triggered by this and her test results at the start (high in calculation and contextual understanding but low in conceptual understanding)

→ **Ownership** by the choice of this MP that allows her to influence her own view of the physics phenomena resistance, current and voltage which she has interest in.

→ **Motivation** can be seen by
- her interactions in exploratory talks
- her interactions in internal teaching,
- her high amount of total talk (29%), physics talk(33%) and planning talk(31%) during work and in total amount of talk in presentation (48%).
- her amount of work in presentation (High).
- her initiative in the explanation in the presentation of voltage by a model that was new to the teacher.

We see motivation as a result of the ownership of the question and also of her competence at start.

→ **Competence** as development of conceptual understanding, holistic understanding and communicative ability
- can be seen as her conceptual change to see resistance at the start as a consumption
of charges into a view of resistance as decreasing current by decreasing current speed (amount of charges/time through a cross section of the wire). This is an increased conceptual understanding.

- her increased self esteem after getting acknowledgment from the teacher that her explanation was new to him and helped him in his development of understanding. This is an increased ability of communicative ability as well.

**Kristin** is positive about working with this MP. She finds everything in physics demanding and is happy if there is something that she can manage to do:

(#{5})

Kristin: So it would be fun if this was fun, I mean...it (physics) is often so difficult it can’t be done!

She takes initiative in the choice of MP and by that she has ownership of the question.

(#{7})

Kristin: In fact it would be best to do something you understand. Something of this kind...

Lena: Yes, something you understand.

Kristin: Something you can see. So you can understand it immediately, it will be like this...

Something that is useful and interesting. What fun is it to do calculations on voltage and potential differences, you don’t even see those odd things.

Kristin shows power to choose activities and to challenge Anna in planning what to do next. That is a sign of high motivation, “more ownership” during work process. She suggests that they should act like a class and that she will be the teacher that is a strong sign of “special action”.

(#{14})

**Kristin:** Can’t we divide ourselves up and pretend to be 7th graders?

Anna: The one who asks lots of questions is...

Lena: ...that’s great....

Lena: I finally understand series circuits... this is the first time!!!

**Kristin:** Let’s take this one and pretend to have a lesson.

Anna: Yes, that would be better.

**Kristin:** Are we going to do that? How fun! I want to be the teacher. Let’s ask if we can do that.

She understands the practical moments to connect in series but has some problem to get into the discussions about resistance and current itself as concepts. One can see her development of understanding of these concepts in the presentation, she has after the discussions in the group learned to explain potential differences for example. At the start her attitude towards potential differences is not that positive. But in the presentation she finds it useful and understandable. We see that as a sign of development of understanding, i.e. competence.

(#{16})

Kristin: Then both wheels will spin and they have the same fall distance. When you have a parallel circuit the current gets divided here and then the wheels turn and the lights go on. Both wheels spin equally fast and because they have the same fall distance...here is where the parallel circuit is stronger...as opposed to the series circuit that has to share the fall distance.

The causal relations for Kristin:
**Interest** in explaining phenomena and **experience** of an analogy as an anomaly. Finds MP as a new chance to understand a physics task.

→

**Ownership by the choice of an MP that will allow** her to develop understanding of this phenomena by training to explain to others and working with something she finds useful and relevant.

→

**Motivation** is seen as
- her initiative and creativity in new activities (challenges to the others)
- her high amount of total talk (21%) and contribution to physics talk (17%).
- persistence to fulfil the task

→

**Competence** is seen in
- her development by use of physics concepts in presentation.
- her ability in the lab work during presentation

**Kathy** has no experience from the analogy with the crocodile. That decreases her possibilities to discuss with the others. Her contribution to the amount of total talk is 11%, and she does not interfere much with the others at the start. Her interest in MP is high considering the fact she finds physics boring:

(#(5))

Kathy: I think anyhow it will be nice to do something of another kind.

We see as a low degree of ownership, her argument to join the MP from fear of being into the same group as some of the clever boys:

(#(3))

Kathy: Well, I don’t want to be with Johan and them…they are just too good.
Anna: It is a good thing that someone is good at it…
Kathy: It just feels like he thinks that I am stupid…
Kathy: I just feel that I don’t want to work with Johan and them, I feel dumb, they can work together…

**Motivation:**
She does 4% of planning talk and 17% of physics talk and 13% of talk in presentation, so her contributions to communication is not that high. This we see as a sign of low motivation in this situation. She is active doing the experimental work and she also takes part in the explanation of the most complicated circuits. In fact her low motivation could be explained by the fact that she finds the task too simple:

(#(9))

Lena: It could be difficult to explain to them.
**Kathy:** Does it have to be that easy?
Lena: What did you say? No, but it is difficult isn’t it? Can you explain to me?

Another sign of low motivation is that she does not try to have impact on the planning; she only takes 4% of the planning talk. But when it comes to presentation she shows her ability and knowledge in lab work and does most of the circuits. She also explains the most difficult circuits. It is not definite this should be seen as a development of competence, maybe she did not learn anything new but it is a sign of increased motivation.
The causal relation for Kathy:

**Interest** in MP is low, she probably finds the task too easy, even if she is not that good in physics.

→

**Low Ownership by the choice of an MP.** It will NOT allow her to work with her own question.

→

**Motivation**
- low in aspects of communication and choice of activities
- increasing when it comes to doing experiments
- high by persisting at task all the time

→

**Competence**
- She contributes well to the presentation and shows the most advanced circuits with nice examples from everyday life.
- no further development of conceptual understanding, holistic understanding or communicative ability can be seen.

6.3  Case 4 – MP To build an Electromagnet and measure its lifting force.

6.3.1  Overview of case 4

PRIOR
John, Harry, Agnes and Erika are all low performers in physics at upper secondary school. They express at the start how they would like to do something practical that you can use instead of only listening to lessons and making calculations. The teacher has problem to convince them that it is not so easy to make a motor car function in one lab session.

They choose a room for themselves far away and as the lab session is in Friday afternoon and they all are tired the teacher expects this to be a catastrophe. They have finally chosen to make a strong electromagnet but they have not expressed any plans how to measure its lifting force, they just start to wind the copper wire.

DURING

The time line

0 - 8 min  Winding copper wire
9 - 12 min  do a first test to see if it functions with a battery
12 - 22 min  It does not work-but why?
23 - 35 min  Teacher gives advice on strategy
36 - 46 min  New electromagnet with iron core-teacher helps
47 - 52 min  Success and count lift power in how many clips it can hold
OUT-COME
The first presentation day only two members of the team show up and they decide to do their presentation at the next physics lesson. When they finally do this the next week they have prepared themselves and three of the group members give a short but nice presentation when they show their results. The teacher interacts with them and is eager to help them to succeed and give correct information to the others as well.

6.3.2 Group analysis-results
Pre conditions:

I Ownership in setting:
They start their project without any discussions and plans. It seems as if their main idea is to first make some electromagnets that work. From initial discussions we see that John is the one who find it interesting to make this electromagnet, the others agree to do as he likes.
The two girls had big ideas of making a car in which they cold use an electric motor they could build. The teacher tries to explain that it is not so easy to do everything at once to produce an electric motor model is enough, but they want to use what they have make to something.

II Interest in Physics:

Fig.6.11 : Harry’s picture of physics in school.
(1) Harry said that physics was easy and nice in secondary school but became very hard in upper secondary school. As he never understood anything it became dull and uninteresting to him.
(2) John also says that physics in secondary school was very interesting and fun, but in upper secondary school he finds it very dull. He immediately found himself left behind and he thinks that was because of that he did not understand the teacher’s explanations and that everything was too quick for him.

(3) Erika writes: I think physics is hard and you do not have time to do so many calculations in school and at home there is no one to help you. That’s why I am not that good in physics. She feels frustrated.

(4) Sara only showed up during this initial discussion. Her picture says “write, write, write, think, think head-ache, tired, swot for the examination, did not understand it at all, frustrated”. Obviously she has a hard time with her physics lessons.
III Interest in MP:
They all trust John and his judgement of the MP and they express this in their final written choice:

(5)
Harry: Jocke said that it was fun, and everything else was boring.
Sara: Jocke said that is was fun and everything else was boring (not everything but it was not the funest thing in the world.)
Erika: no statement
John: It seemed fun. Everything else was boring.

The group have a lot of thoughts about what they would like to do in physics and the main idea is to produce something that works and is useful. They argue with the teacher about this. Harry supports the girls in this discussion and tries to make the teacher understand that they learn best if they do something practical, otherwise they lose interest because it becomes so tiresome.

(6)
Erika: (Turning to the teacher) Could I get some help? If we make small radio controlled cars. We each make a motor. Then we can put it in a car. Then we can see which one goes the fastest.
Teacher: This motor is too weak…(hard to hear the tape)
Erika: Could we make it stronger?
Harry: Mine will run on gasoline and everything.
Teacher: (unintelligible) …We can’t make a motor that can be used.
Erika: Why can’t we learn how to do that? I have seen many from 3rd grade that can do it.
John: Yes, why can’t we do that?
Erika: Build something from scratch and then connect something…!
Harry: That is when you learn the most!
Erika: It is so fun to do.
Sara: Maybe not with this project…but instead of…
Harry: Instead of lectures, listening and doing homework all the time everyone gets so tired of that.
Erika: Instead of …what are they called…labs …we build something! Yes, this is for building…but we can’t use it for anything.
Sara: We can just get started.
Erika: Are physics and technique the same thing?

They make a judgement of how difficult the task could be? They find it easy to do.

(7)
Sara: It really isn’t that hard to connect that?
Erika: No, it isn’t that hard.
John: It’s a battery so it really isn’t that hard. Just connect the wires to a battery. Then we explain it too. That can be difficult.

Erika is still not enthusiastic but the others try to convince her that this is the best MP:

(8)
Harry: Lets get going on this Erika, the electromagnet.
Erika: How much can it lift?
John. This is so much fun!
Erika: Fun?
Harry: Yes, fun.
Erika: Are we only going to do this one?

IV  Competence:
The physics test with five questions in formula calculations, five in conceptual understanding and five in holistic understanding could give maximum (5,5,5) points. Harry (1,1,2), John (1,1,2) Erika (1,2,1,) Agnes (not present), Sara(3,1,4)
The competence test says that this can be a low performing group. What will happen then in an MP situation?

During:

V Communication aspects:
There were no signs of exploratory talks or internal teaching.

Communication content:

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 physics</td>
<td>25%</td>
</tr>
<tr>
<td>2 exploratory talks</td>
<td>0%</td>
</tr>
<tr>
<td>3 Concepts</td>
<td>0%</td>
</tr>
<tr>
<td>4 Instruments</td>
<td>18%</td>
</tr>
<tr>
<td>5 Math</td>
<td>0%</td>
</tr>
<tr>
<td>6 &quot;Non-task related&quot;</td>
<td>42%</td>
</tr>
<tr>
<td>7 Planning</td>
<td>14%</td>
</tr>
</tbody>
</table>

Table 6.6: Amount of talk divided in categories (% of total talk)

They have a nice Friday afternoon winding their electromagnets. They are chatting about everything out-side the task. Analysing the talk we see that 25% still is about physics, but as much as 42 % is non-task talk. 14 % is about planning what to do next. They go on with their non- task talk for a long time but as nobody stops them, they seem to realize that it is up to them to produce some results. Agnes and Harry talk physics almost not at all. The teacher goes into this group and talks with them after they have made their first electromagnet which does not succeed in lifting anything. His contribution changes the group’s possibilities dramatically, and he helps them with a strategy for their investigation.
The teacher’s assistance in this group is priceless. He is relaxed, interested, helpful and sensitive to what is going on in the group. He identifies the problem: They took as an iron-core a non-ferrous piece of metal that did not strengthen the magnetic field of their first magnet. They go and get new iron-cores and they start with a better probability this time.

**VI Ownership:**
Concerning planning this shows how the teacher goes into the group and helps them organize their task. He stays for 50% of the planning talk. John contributes with 10%, and Agnes with 13%, Erika with 15% and Harry with 7%.

<table>
<thead>
<tr>
<th></th>
<th>John</th>
<th>Agnes</th>
<th>Erika</th>
<th>Harry</th>
<th>Teacher</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount</td>
<td>3:</td>
<td>4:</td>
<td>6:</td>
<td>2:</td>
<td>22:</td>
</tr>
<tr>
<td>%</td>
<td>10%</td>
<td>13%</td>
<td>15%</td>
<td>7%</td>
<td>50%</td>
</tr>
</tbody>
</table>

Table 6.7: Individual amount of talk marks for planning (number of marks: % of all planning talk).
When the teacher has helped them with a strategy, they all get enthusiastic about the task and there is a complete change in attitude.

**VII Motivation**
Effort: John is especially interested in making a better electromagnet. After discussions with teacher they have realized that the material in the iron core is not iron at all and they now have help to make magnets with good ones and they use three iron nails inside. Now they can measure lifting power in how many clips the magnet can lift.

Persistence: They stay with the task for the whole afternoon, 80 minutes.
Energy put in during process:
Percentage of physics and conceptual talk divided by person show that John (28%), Erika (31%) and Teacher (33%) are dominant in physics talk but Agnes (5%) and Harry (3%) do talk physics almost not at all. In talk about planning it is obvious that the teacher is dominant with 50% of all planning talk together with Erika 15%. The amount of disturbance in form of talk with non-MP content was very high, 42%, and the energy put in on the task is low when it comes to talk.

But these students are doing something all the time that is connected to the task's performance, as an example Harry, who struggles with the big coil of copper wire (that has become tangled after a student collected some wire for his electric motor MP. They are chatting and having a good Friday afternoon, talking about all that happens to them and in the mean time winding the copper wire and doing some experimental work. It is badly organized and planned for and they are not focused on physics. They do not have words to communicate about the physics as they do not even know the function of the magnetic field inside a coil. But they discuss what they find the important part, to get the magnet to work and become useful to them. They want the electromagnet to function but they do not discuss how they will make it function. Without help from the teacher they have not succeeded but as he gave them input at the right moment the felt the project had a happy ending.

<table>
<thead>
<tr>
<th></th>
<th>Physics</th>
<th>Instrument</th>
<th>Maths</th>
<th>‘Weather’</th>
<th>Planning</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>John</td>
<td>11</td>
<td>8</td>
<td>9</td>
<td>3</td>
<td>31</td>
<td>20%</td>
</tr>
<tr>
<td>Agnes</td>
<td>2</td>
<td>2</td>
<td>23</td>
<td>4</td>
<td>31</td>
<td>20%</td>
</tr>
<tr>
<td>Erika</td>
<td>12</td>
<td>8</td>
<td>13</td>
<td>6</td>
<td>39</td>
<td>25%</td>
</tr>
<tr>
<td>Harry</td>
<td>1</td>
<td>7</td>
<td>20</td>
<td>2</td>
<td>30</td>
<td>20%</td>
</tr>
<tr>
<td>Teacher</td>
<td>13</td>
<td>2</td>
<td>0</td>
<td>7</td>
<td>22</td>
<td>14%</td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>27</td>
<td>65</td>
<td>22</td>
<td>153</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>25%</td>
<td>18%</td>
<td>42%</td>
<td>14%</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

Table 6.8: Percentage of physics and conceptual talk divided by person (marks and %)

Outcome:

**VIII Quality of work:**
Amount of work: Medium

Development of competence
That all students realized that the material in the core was of importance can be seen as a development of understanding. In presentation they are not sure if the electromagnetic field is there without a core so there are still problems in
understanding for at least two group members. They also managed to fulfil their presentation and presented some theoretical views about magnetic domains at that time, which also is a sign of development in understanding.

Development of self confidence and self esteem
As soon as they realized it was up to them to get some results they changed attitude towards a more efficient view of carrying on with task. They express curiosity and pride in the result.

IX Quality of output:
Presentation:

John draws a diagram of an electromagnet that is made from three nails wrapped with wire and another one made from one nail also wrapped with wire.

(10)
John: You were going to talk while I draw!
Agnes: We made an electromagnet from nails wrapped in copper wire. We made two, one with one nail, and one with three. The one with three nails was naturally three times as strong as the one with only one nail.

Student: Why?
Agnes: Well...Nails are made of iron and iron is a good conductor. Since iron is composed of small magnetic domains and when one sends current through it the magnets line up. That is why it is so strong.

John: You send a current through this (points to the copper wire) and then they become magnetic (points to the nails.) This is much stronger that that (points to the electromagnet with 3 nails)
Harry: We didn’t wind this one as much as the other one (points to electromagnet with three nails)
but....
John: But this one had many revolutions of copper wire. (pointing to the electromagnet with one nail.)
Harry: And it was better anyway. (the one with three)
Teacher: May I ask a question-The current that goes through the wire, does it go through the nails too?

John: No. There is a substance on the wires- what is it called- something that isolates.
Teacher: Yes, it is a type of paint. If one does not have nails is it still an electromagnet?
Harry: Well...there are magnetic domains in the nails, the more the stronger the field.
Teacher: If you take away the nails will there still be a magnetic field?
Harry: No.
John: I think that we forgot to try that. (class laughing)
Teacher: There is a magnetic field but it is much weaker. After a certain number of nails it wont get any stronger. It is not necessarily 3 times stronger with three nails instead of one. You get to a certain value and then it does not get stronger.

The group have finished their presentation. As one of the listeners I add another question.

(11)
Margareta: Do you know of any practical uses for electro magnets?
John: No. (I am sure he does, but he finds his presentation is over.)
Student: Junk yard, trains with electro magnets in Japan that float over the tracks.
Teacher: There are locks that are based on electro magnets. When you turn on the light in a car there are electro magnets involved. An electro magnet that turns something on is called a relay. At steal mills giant electro magnets are used to lift large slabs of steal, just like at the junk yard.
6.3.3 Summary

Interest in physics
They all state that they do not keep up with physics teaching. The speed is too high and never understanding makes the subject dull and uninteresting to them. They feel frustrated with the situation and long for help. One view is that the situation has impact on their health they get head-aches and feel bad.

Interest in the MP
One of the girls has strong arguments for producing something that is needed for some purpose. She longs for an overview, it is not enough to build an electric motor model even if that is not that bad, but the motor has to do something. She wants to build a car and put the motor inside then it could do something. As the others find it too complicated, she turns to the teacher hoping for his help:

Erika: (turning to the teacher) Can I get some help? If we make small radio controlled cars…We would each make one. Then we would mount it in a car. Then we can see which one goes the fastest.

The others trust John, who finds the electromagnet MP nice and understandable.

Ownership at start
The design gives the group ownership of the MP. In fact it is only John who has ownership of the question; he wants to build a strong electromagnet. Sara and Harry are loyal to him but Erika has to be talked into this project. See (5).

Competence
They group showed very low competence in the test. Agnes was not present.

Communication
They show no sign of strategy to solve the task, in the meaning of making magnets and measuring their lifting capacity. Their intention is to make some magnets that work.
That is what occupies them at first and they all make their own magnet. During their work they talk most of the time about non-task questions. It is like a sewing circle, they do handwork and through that they are free to talk about others things, like women doing a piece of needlework talking over some topic of conversation. When the magnets do not work the teachers helps change the atmosphere in the room. Without his driving force by planning talk with them, I doubt if anything would have come of it. Harry and Agnes do not have Swedish as their first language.

Motivation
A sign of motivation as particular action is when John together with the teacher finds new materials for the iron core. Another sign is when Agnes goes to find help from the teacher. They all stay around the power supply and find it interesting to count how many paperclips the magnet can lift and by that they show motivation.
They persist with the task the whole session and they continue to prepare for the final presentation at home.

Quality of output
This low performance group needed the teacher's help to manage their task but as the teacher was available he felt he had time to help them without neglecting somebody else, because they were more successful in the other projects at that time. John took responsibility for the task all the time but they all seemed to be happy for the good results they achieved. It was interesting to follow this process where they realized that they had to decide themselves if they should try to solve the problem or not. Maybe students have to make that decision themselves. This shows that ownership is important to create motivation, even if the results are not always that impressive. Agnes and Harry were quite a trial to the group with their constant chatter but in the end they all became interested in the strength of their magnets which is a sign of ownership related to motivation. They made a nice presentation, but no written report.
### 6.3.4 Discussion about evidence

**Fig. 6.16: Summary of variables for Case 4 The Electromagnet MP Group at Upper Secondary School.**

<table>
<thead>
<tr>
<th>BEFORE</th>
<th>START</th>
<th>WORK PROCESS</th>
<th>OUT –COME</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRIOR</td>
<td></td>
<td>DURING</td>
<td>FINAL</td>
</tr>
</tbody>
</table>

#### INTEREST

**II in physics:**
- to difficult (1)(2)
- to high speed (1)(2)
- bad change from secondary school

**III in CRP:**
- fun ()
- to difficult ()

#### RESULT IN TEST

**IV Competence:**
( calc, concept, under, contextuel under)
max(5,5,5)

- John (1,1,2)
- Harry (1,1,2)
- Agnes – no test

#### OWNERSHIP

**I Own at start:**
John finds a unique question, he has seen and made an electromagnet before.

Erika is persuaded into the MP.

The others show trust in John, if he finds it fun it is fun.

#### MOTIVATION

**V Communication:**
Content in group talk:
- Physics related (25%), Equipment (18%), Math (0%)
- Planning (14 %), Non-task-talk (42%)

Individual talk:
- John (20%), Agnes (20%), Erika (25%), Harry (20%)
- Teacher (14%)

**VI More ownership:**
Individual planning talk:
- John (10%), Agnes (13%), Erika (15%), Harry (3%)
- Teacher (50%)

**VII “Motivation”:**
Individual physics talk:
- John (28%), Agnes (3%), Erika (31%), Harry (3%)
- Teacher (33%)

Persistence: high spent in school and at home
Effort :. Change material in iron-core. Go for help from teacher.
See VI and V
Achievements: Fulfill ambitions

#### COMPETENCE

**VII Quality of work**
Amount of work (58% of all talk concern the task)
Development of:
- understanding of physics:
  understand importance of iron core in electromagnet
- holistic understanding of physics: some notes about electromagnets in society
- self-confidence by experience of own abilities and letdowns:
  Yes: manage to fulfill presentation
- competence by communication training:
  yes

**IX Quality of out-put.**
See text
John has problems with physics understanding due to the fact he cannot keep up with the speed of the teaching. He has been interested in physics and has found physics in secondary school interesting and fun. He becomes something of a leader in this lab group constellation. He seems to feel responsibility to get the job finished and shows ability in many ways, he discusses physics with the teacher, he produces the first magnet and he changes to an iron-core. He also gets the point with three different iron-cores to get different magnetic field strength and the possibility of changing the number of windings or revolutions in the coil. He is the one that communicates with teacher, the others seem to hang around and have a more passive part in the project.

The causal relation for John:

**Interest** in core physics and **experience** of how to build an electro-magnet.

→ **Ownership by the choice of an MP.** He will be able to fulfil this task, as he understands how to do it.

→ **Motivation** by effort seen as communication: He takes a great deal of the physics talk (28%) together with Erika (31%) and the teacher (33%). He shows some special actions of motivation when he goes for changes in the magnet design. His planning discussions with the teacher became crucial for the project to succeed. He produced the first magnet that works and can lift a lot of paper clips. He takes the leading part in the presentation.

→ **Competence as** development of conceptual understanding: At the end he was aware of the importance of the material in the core of the coil and even more obvious the importance of a strategy to compare and show some results. This is a sign of holistic understanding.

Erika has a great amount of energy but shows great frustration at not keeping up with physics teaching. She searches for an overview and expresses the lack of holistic understanding she finds. She does not see the complexity of a motorcar but finds it something to be done at once. She would like to learn something she finds useful and that she finds meaningful. She does not like the electromagnet MP but as the others do not agree with the electric motor MP, she joins the group. She thereby has low ownership of the MP. During work she finally engages herself in the MP and with John becomes one of the most import people for the task to be done. We find that to be a consequence of her ability and will to succeed and a sign of motivation. She drops out of presentation in two occasions and that we see as low motivation.
The causal relation for Erika:

**Interest** in holistic but not conceptual understanding in physics so far. No **experience** of electromagnets before.

→

**Ownership by the choice of a MP**: Low ownership at start. She prefers another MP.

→

**Motivation by effort seen as communication**: She takes a great deal of the physics talk (31%) together with John (28%) and the teacher (33%). She takes some special actions of motivation when she goes into the planning and physics discussions with the teacher. She is very interested in their finally good result and takes part in the measurements. She drop out from the presentation twice and do not do her part of the presentation.

→

**Competence as some** development of conceptual understanding and holistic understanding concerning electromagnets.

---

Agnes was not present on two occasions, she gave no view of physics and she gave no physics test. She talks a lot (20%) but she does not talk much physics (5%). Her ability is low so far in physics. She has been working with Harry and John in laboratory work before and communicates with them with jokes and chatter. She gives an impression of being at the same time very self-confident and unsure and it is not easy to find signs of this MP being relevant to her.

---

The causal relation for Agnes:

**Interest** in physics not specified no **experience** of electromagnets.

→

**Ownership by the choice of a MP**: Low, she does what John finds to be a nice MP.

→

**Motivation by effort seen as communication**: Low contribution to physics talk and planning (13%). Finds the final results great fun and counts the paperclips and expresses how much fun she finds it to be in this project. Low amount of work but active in the presentation. Puts her in the focus of conversation but has low input concerning physics.

→

**Competence as some** development of conceptual understanding, holistic understanding, communicative ability seen during presentation.

---

Harry also has problems with physics understanding due to the fact he cannot keep up with the speed of teaching. He has been interested in physics and has found physics in secondary school interesting and fun. He does not have Swedish as his first **language** and he often start sentences without ending them as if he can not find the proper words to express himself. He trusts John as the informal group leader. He makes jokes, especially with Agnes, but talks little physics in group. In presentation he shows knowledge about magnetic domains, a sign of how he has prepared for the presentation with new facts inspired from the laboratory work. He is nervous and talks about pains in his stomach. He feels pressure at school.
The causal relation for Harry:

| Interest | in physics has decreased in gymnasium due to the speed of the course. No experience of how to build an electro-magnet and no special interest in the MP. |
| Ownership by the choice of a MP: | Low, he does what John finds a nice MP. |
| Motivation by effort seen as communication: | Low contribution to physics talk (3%), and planning talk (3%), but takes a big part of total talk (20%). He is chattering, and gives the impression of not really knowing what to do next. He shows will to contribute but for the moment in work process he does not show the ability to contribute much to the task. He tries the whole time to tidy up the copper wire coil that got tangled at the beginning of the laboratory session. In presentation he explains magnetic domain. That is a sign of new facts inspired from the results during lab session and a sign of motivation. |
| Competence as some development of conceptual understanding by the concept of magnetic domains and some holistic understanding by the electromagnet experience and communicative training. |

Chapter 7  Context Rich problems (CRP)

7.1  Overview of CRP used

The upper secondary school small groups of students got two CRP to solve during approximately two hours. They could use as much time they liked for the first problem. The second problem is not analysed in this study.

1  The Clay

You have a lesson in electricity. The teacher is searching for a 1 kΩ resistor to use in a circuit you will need in your lab. You play with a multimeter, and you measure the resistance in a cylinder shaped piece of play-clay, that you happened to get with you in your pocket when you was plying with your youngest brother. The multimeter shows 250 Ω. Then you get an idea to produce a resistor yourself. Will it be 1 kΩ if you just make a roll of the clay and make it twice as long as it is now? Then it will fit into the holder in the lab equipment you need to use.

Give a report of assumptions, calculations and conclusions.

2  The Fish

You are a student at the Department of Biology and you work with electric fishes as speciality. Your task is to draw up instructions for how one could get closer to an electric ray that is located in a basin outside the department. The electric ray is a strong current fish and could be dangerous to meet in the water. You know that this fish has 200 electrolyte cells connected in series in each pile, and you think it has approximately 2000 piles connected in parallel. The fish can give current up to 50A.
From what direction can one get closer to the fish, f towards it head, its tail or maybe from the side? Draw the electric field the fish can produce and calculate its power.

Get information from the article below.

Fig. 7.1: Electricity as protection and guidance by André Olsson
http://www.biol.lu.se/zoofovisol/Djurartiklar/Elfisk.html

7.2 Case 5 CRP The Clay – Anna-Lena-Kathy
7.2.1 Overview of case 5
PRIOR
The three girls here called Ann, Kathy and Lena are ambitious and successful girls in physics classes. They find physics boring and demanding and are quite critical of physics in school. Before they start this CRP session they have done a physics test and answered questions about school physics. This will be their second meeting with the research team from Mälardalen University and they are quite excited about the video camera and about being put into different group rooms.

DURING
They start at once by reading the text and they follow this timeline:
Identify the problem-Variation in the idea of what the problem is
After 4 min:
Anna: But how does one count ohms?
Kathy: Is R in ohms?
Lena: Mumble…laugh…mumble.

Problem solving strategy
After 6 min:
Kathy: But does it really matter how long it is? I mean…its width decreases but it is the same resistance…the volume is the same?
Lena: In the case where you have…a wire that is long there is a difference, but in this case it is the same.
Anna: but, the question is, it has longer to go to like…
Kathy: yeah…
Lena: Yes, now…yes that’s right…it get narrower too.
Anna: it becomes wider.
Lena: It is short and wide. Short and wide gives less resistance than long and thin.
Kathy: Oh, so its like the electrons have to spread out here.

**Solve the problem**

After 17 min:
Lena: Here it is \( \frac{1}{2}A \), we…
Anna: We may write it in some way…
Lena: …it looks like this…
Anna: We need to call it something. Don’t you need to do 21?…
Lena: Right, 21 divided by half of A.
Anna: Yeah, that’s what it is.
Lena: (writes, mumbles.)

**Reflecting over the results**

After 27 min:
Anna: Oh, is that what you think, I thought it was the formula.
Kathy: Or like this...OH. It is the same thing.
Lena: Exactly. It is the same thing.
Kathy: Then the length is twice as long and the area half the size.
Anna: It is the same thing as there…
Lena: Is it alright if we write the equation like this, do you believe me?
Anna: Do you trust us?!
Lena: Write.
Anna: Write 41 as you like. Use an example.

**The CRP problem solving timeline**

<table>
<thead>
<tr>
<th>Category</th>
<th>Time</th>
<th>Individuals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Realises the volume is constant.</td>
<td>6.25</td>
<td>Kathy: But does it really matter how long it is? I mean…its width decreases but it is the same resistance…the volume is the same?</td>
</tr>
<tr>
<td>Realises that ( R ) increases with increased ( l )</td>
<td>6.40</td>
<td>Lena: Yes…Yes thats right…it becomes smaller too. Anna: den blir ju bredare...It gets wider.</td>
</tr>
<tr>
<td>Realises that ( R ) decreases with increased ( A ). (inverse proportionality)</td>
<td>6.40</td>
<td>Lena: It is short and wide, short and wide gives less resistance than long and thin.</td>
</tr>
<tr>
<td>Inser att flera variabler påverkar ( l.A ). Realises that several variables affect ( l.A ).</td>
<td>8.54</td>
<td>Lena:. I actually think that it can be 1000Ω, it is not just the increased length because the width is also smaller.</td>
</tr>
<tr>
<td>Realises that the resistance is the same.</td>
<td>7.25</td>
<td>Anna: Yes, if it is the same composition as the modelling clay.</td>
</tr>
<tr>
<td>Recognises the formula.</td>
<td>9.06</td>
<td>Lena: There is an area formula.</td>
</tr>
<tr>
<td>Realises that ( \rho ) is the symbol for resistance.</td>
<td>9.50</td>
<td>Anna: It has something to do with lengh and area. Lena: Here it is… Anna: What it the constant then…( \rho ) Lena: It is ( \rho ) that is density. Anna: Density can be calculated. One has it.</td>
</tr>
<tr>
<td>Realises same symbol for several quantities, density, resistance, ( \rho )</td>
<td>10.53</td>
<td>Anna. (looks in the formula book) They didn’t have modelling clay. Otherwise they usually have lots of weird things. Lena: Is there anything like it?…then you could guess…Is clay in there? (Anna looks in the formula book)</td>
</tr>
<tr>
<td>Time</td>
<td>Lena:</td>
<td>Anna:</td>
</tr>
<tr>
<td>-------</td>
<td>-------</td>
<td>-------</td>
</tr>
<tr>
<td>12.06</td>
<td>.I still think it will be this way. But yes…</td>
<td>But can’t we set this to 1, radius 1 to the length to 1 if…or we set x, we calculate with x and then set x by something-and then we can to something, I don’t really know what.</td>
</tr>
<tr>
<td>17.10</td>
<td>We have to write it down…</td>
<td>...it looks like this..</td>
</tr>
</tbody>
</table>

### OUTCOME

The presentation of their results does not give a fair description of their effort in this problem solving. It consists of some notes of the final conclusion but is correct in all parts.

Fig.7.2 Report of CRP

### 7.2.2 Group analysis - Results

#### PRIOR

1. **Ownership in setting:**

   The group has no impact on content and question. They have to solve this problem as all the other groups had to. They are free to communicate about the problem and to spend time in different parts of the problem solving. If they have experiences explanations and anomalies from earlier this will show up during this session.
II Interest in physics

View of school physics:

Anna:

“I find it (school physics) rather difficult. It is hard because you have to understand, calculate and read at the same time. But it (the result) has been quite good so far. Also, the books are very boring.”

Fig. 7.3: Anna’s view of physics in school.

Lena:

“Booooring. Often rather difficult as well. Many parts are interesting if you have time to think about it but that time does not exist. It is all about understanding as fast as possible and then reading it for the test, and then moving on.”

Fig. 7.4: Lena’s view of physics in school.
Kathy:

“Physics can be interesting when you can keep up (with the teaching) and understand, but if not, it is hard not to think it is hard and boring. Tough!”

Fig. 7.5: Kathy’s view of physics in school.

From pictures and statements the girls find school physics difficult and boring. The reasons for this are explained by the speed which leaves no time for reflection. To be sitting too long working hard is arduous even if physics itself is interesting.

III Interest in CRP:

They show a very positive attitude towards the session with CRP work. They are almost excited to start with the task and there is some competition in the air as the other groups are doing the same task.

Everyone reads and looks through their formula books.

***

Getting engaged with the problem.

Anna: They are ahead of us. (Can’t find what she is looking for in the formula book.)
Lena: You are the worst with the alphabet.
Anna: Should I be offended?

IV Competence:

The physics test with five questions in formula calculations, five in conceptual understanding and five in holistic understanding could give maximum (5,5,5) points. The four girls got: Ann (4,1,4) Lena (4,3,4) Kathy (4,2,5) and Kristin (2,2,5). They are all of them strong in holistic understanding but not that good in conceptual understanding.

DURING:

V Communication:

Interactions between students during the group discussion are of different types. When it comes to development of conceptual understanding the girls go into exploratory talks. This kind of talks is described in literature. (Barnes 1976; Barnes 1977). They can be seen as an attempt to reach conceptual understanding or to
maintain a conceptual change. They need to talk to a person they trust and who joins
the searching for a solution to a feeling of an error in their view of some phenomena.
In this situation Anna and Lena use exploratory talks to help each other recognize the
resistance in wires...

**Exploratory talks**
Anna: It was something about how to use Ohm’s law...
Lena: Yes, that’s what it was.
Anna: ...it was dependant upon the length and the area...
Lena: ...cross section.
Anna: ...Here it is R that is resistance.
Lena: ...Yes, but then you have to have...
Lena: ...Yes…we can write the formula too. Do you recognize it?
Anna: ... Yes it has something to do with length and area in the formula.
Lena: There it is. Do you recognize it?

**Internal teaching**
Another type of communication seen is what we call internal teaching. Lena is pretty
sure of her knowledge of this and goes for explaining the phenomena to Kathy who
has never heard about it....
Kathy: This is stupid, I don’t think there should be any change because….  
Lena: But if you have a copper wire that is this long (stretches out his arms) then there is a lot of
resistance. But if it is short and thick (uses his hands), then there is little resistance.
Kathy: Yeah, I guess.
Anna: Then there is room for many in the tub…You need to think about water, like you did in 9th
dergade.

**Other forms of communication**
They are very polite to each other and give each other confirmations that they have
got the point of the other person's ideas:
Kathy: But I am thinking about a really long rope that you fold up.
Anna: Then lets fold it up !
Kathy: Yes, I know, but I assume that it is the case.
Lena: O.K., so that’s how you think.

Another example of this phenomenon:
Kathy: So half of it will be there.
Lena: That is what you say.
Anna: That’s what you say.
Kathy: No. (takes the paper)
Anna: 21 divided by ½A is it. Then you have the formula and if you expand it with 2 and multiply
with 2 then you get 41. That is how it is done.
Lena: Are you in agreement?
Kathy: The length is shortened when the area increases. Look! If you take half it is not 41.
Lena: Are you in agreement then?
Kathy: Yes, I agree with it.
Lena: But.
Anna: But it does not make any difference, we need an answer!
Lena: That is what we did. We have to be in agreement, all of us. But we are not in a hurry. Do
you know what to do if you look at it a little…and then you say...

Some examples of what disturbs the communication came from the task itself:
Anna: Yes, she was playing with her little brother… (smiles).
Lena: Oh…heehee.
Kathy: And is it still in the form of a cylinder after it had been in her pocket?
Lena: Yes, that kind of thing bothers me.

Kathy loses her enthusiasm when they find another difficulty in the problem: They have started to discuss if the material has impact on the resistance and want to find some values in their tables about the resistivity of different materials. (In fact they search for density because they misunderstand the symbol in the book with formulas.)
Lena: Is there anything like that? Well, you can guess. Is there any clay? (Anna looks in the book of formulas)
Kathy: Damm
Anna: There is both glass and water.
Lena: Clay?

Communication content:
We can see how Kathy's talk is increasing during the three parts of the session, and we see this as an increased motivation when it comes to mathematical problem-solving which she likes. They are all very focused on the task, only 12% of the talk concerns non-task talk. In total Lena does 40% of all talking, Anna 35% and Kathy 25%, which gives the group an equal profile when comes to communication.

**VI Ownership**

Negotiation over what to do next is seen:

Lena: I’ll take notes.
Anna: Shouldn’t we all take notes?
Marg: We don’t need to be so …
Lena: One set of notes per group?
Marg: Yes, one per group.

They do not spend much time on planning (8%) but the planning category is not equal in the group. Lena takes 67% of the talk in this category, Anna 25% and Kathy only 8%. This gives Lena strong ownership to the task.

**VII Motivation**:

As signs of motivation we see choice of a particular action. Lena show this sign of motivation at the start when she will go for the 'secretarial' work:

Lena: I’ll take notes.
Anna: Shouldn’t we all take notes?
...
Anna: Write down everything in case we think of something.

**Persistence with the task**

They work hard and the total time spent on the problem is 30 minutes but the problem was solved after 17 min.
<table>
<thead>
<tr>
<th>NUMBER OF WORDS</th>
<th>Lena</th>
<th>Anna</th>
<th>Kathy</th>
<th>The number and percent of words per category.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>847/2110=0.401 40,1%</td>
<td>732/2110=0.347 34,7%</td>
<td>531/2110=0.252 25,2%</td>
<td>100,0%</td>
</tr>
<tr>
<td>Physics-physics concept.</td>
<td>335/837=0.400 40%</td>
<td>276/837=0.330 33%</td>
<td>226/837=0.270 27%</td>
<td>837/2110=0.397 39,7%</td>
</tr>
<tr>
<td>Result-planning</td>
<td>115/171=0.673 67%</td>
<td>42/171=0.246 25%</td>
<td>14/171=0.082 8%</td>
<td>171/2110=0.081 8,1%</td>
</tr>
<tr>
<td>Talking that is unrelated to the assignment.</td>
<td>117/256=0.457 46%</td>
<td>105/256=0.410 41%</td>
<td>34/256=0.133 13%</td>
<td>256/2110=0.121 12,1%</td>
</tr>
<tr>
<td>Mathematics-Formulas.</td>
<td>280/846=0.331 33%</td>
<td>309/846=0.365 37%</td>
<td>257/846=0.304 30%</td>
<td>846/2110=0.401 40,1%</td>
</tr>
<tr>
<td>Total</td>
<td>847</td>
<td>732</td>
<td>531</td>
<td>2110 100%</td>
</tr>
</tbody>
</table>

Table 7.1: Amount of words used in categories and by individuals

Percentage physics and concepts talk of total talk
The group spend 40% of the talk on physics and conceptual talk, compared to 40% mathematics talk and 8% of planning talk. This must be seen as a strong result for the CRP as an instructional design.

OUTCOME

IX Quality of work:
Amount of work: High

Development of competence:
We see improvement of conceptual understanding of resistance in wire. Their experience of anomalies comes into the light and their internal teaching helps all three to understand the problem solving. The mathematics is a large part of the problem and here the difficulties come to the surface and they discuss and agree finally on the solution.

Development of ownership
Kathy, who starts with a low profile, increases her ownership. This can be seen in her increased talk when it comes to mathematics.

X Quality of output:
Presentation: No presentation of results is made.
Physics: good; Amount of work: High; Physics and Mathematics talk. High 40 %, 40 %

Products:
Report: Correct; Physics: Advanced; Amount of work: Low

XI Evaluation

Evaluation – signs of interest
"It was fun, but the fish was a little hard to film with the camera and the tape recorder but I got the hang of it after a while.”
(Kristina)

"It was fun to work in a group. It alloys you reason with others and hear ideas that you might not of though of. There wasn’t the same kind of pressure to finish the assignment. It is nice to have non-conventional assignments. “
(Lena)

” It was rather fun. Nice to have a change of pace instead of the usual ‘listen and calculate’ method. The modelling clay was more fun than the fish. I was more successful with it as well. After a while I didn’t even notice that the camera was filming us.!
(Anna)

Discussion:

The possibility to communicate strengthens the possibilities of development of conceptual understanding as it gives opportunities to join the exploratory talks with peers or to join internal teaching that is probably just as useful for the peer “teacher” as for the peer “student”. Their interest in physics in school are not high at the start, so every step towards more freedom of choice of activities that lead to learning are welcome from students' point of view. They show high motivation during this CRP as can be seen from the low part of talk in non-task matters(12%). Their ownership will maybe be greater if students are allowed to choose problems themselves so all groups do different tasks.

7.2.3 Summary

Interest in physics
They find physics interesting but demanding, and point out the lack of time for reflection of what it is all about.

Interest in the CRP
Positive attitude and they act if it is a problem for a prize competition. They listen to the room nabours and here from their voices if they are behind (#(4)): Anna: They got ahead of us. (Doesn’t find what she search for in the formula-book)
Ownership given from the instructional design
All groups do the same CRP. This is of course not necessary. In fact a way to increase the group ownership at start is to give all the groups different CRPs. Individual ownership is by chance, they are not able to choose a topic that is more interesting to them then other topics.

Competence
The physics test with five questions in formula calculations, five in conceptual understanding, and five in holistic understanding could give maximum (5,5,5) points. The four girls did: Ann (4,1,4) Lena (4,3, 4) and Kathy (4,2,5). They are all of them strong in holistic understanding, but not that god in conceptual understanding.

Communication
They use exploratory talks and internal teaching. They are very eager to reach consensus before leaving for next task. They are much focused and use only 12% of their conversation in non-task talk. They are quite equal in talking. Anna 35%, Lena 40% and Kathy 25%. They talks physics in 40% and they talk mathematics in 40%, a big difference from the MP talk where there were almost no mathematics talk.

Motivation and ownership during work
They are very motivated, i.e. they use 88% of their conversation during these 30 minutes in task-related talk. They talks physics in 40% and they talk mathematics in 40%, a big difference from the MP talk where there were almost no mathematics talk. Lena is driving the problem forward, she take 67% of the planning talk, compared to Anna 25% and Kathy only 8%. Lena is very motivated to the task.

Development of competence
They solve the problem after 17 minutes, but use still 13 minutes to check that all agree of the result. As they go different way in their ways to the final algebraic expression, all this time go to mathematics. They discuss how to divide by a fraction in algebraic notations with letters. This we see as an increased competence in communicating physics for all three girls.

Development of self-confidence and self-esteem
When the groups discuss their results the girls find that they have succeeded to solve the problem. This makes them very satisfied with the effort made.
### 7.2.4 Discussions of evidence

<table>
<thead>
<tr>
<th>BEFORE PRIOR</th>
<th>Start of MP START</th>
<th>WORK PROCESS DURING</th>
<th>OUT –COME FINAL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INTEREST II in physics:</strong></td>
<td><strong>OWNERSHIP I Own at start:</strong></td>
<td><strong>MOTIVATION V Communication:</strong></td>
<td><strong>COMPETENCE VII Quality of work</strong></td>
</tr>
<tr>
<td>if time for reflection if meaningful</td>
<td>No possibility to choose topic</td>
<td>Use exploratory talks (5) Use internal teaching (6) Disturbances (9), (10)</td>
<td>High amount of work (88% of all talk concern the task)</td>
</tr>
<tr>
<td><strong>III in CRP:</strong></td>
<td>No possibility to choose unique and own question</td>
<td>Content in group talk: Physics related (40%), Math (40%), Planning (8%), Non-task-talk (12%)</td>
<td>Development of: understanding of physics: mathematics in problem solving improved - holistic understanding of physics: to find the problem inside the story -self-confidence and self-esteem by experience of own abilities and letdowns -competence by communication training high</td>
</tr>
<tr>
<td>same CRP in all groups create competition find it fun and nice for the sake of variety</td>
<td>Possibility to communicate by each other in exploratory talks</td>
<td>Individual talk: Anna (35%), Lena (40%), Kathy (25%)</td>
<td><strong>IX Quality of out-put</strong></td>
</tr>
<tr>
<td><strong>RESULT IN TEST IV</strong></td>
<td><strong>VI More ownership:</strong> Individual planning talk: Anna (25%), Lena (67%), Kathy (8%)</td>
<td><strong>VII “Motivation”:</strong> Persistence: 30 min Effort : See VI and V Spend a lot of time to reach consensus of concepts descriptions</td>
<td>See text</td>
</tr>
<tr>
<td><strong>Competence:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(formula calc, conceptual understanding, contextual understanding) Anna (4,1,4,) Lena (4,3,4) Kathy (4,2,5) Kristin (2,2,5) (good, weak, strong)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig.7.7: Summary of variables for Case 4 The Electric circuits MP Group at Upper Secondary School.
**Lena** is driving the CRP forward with 67% of the planning talk. Her motivation we see as it comes from her longing for reflective physics (2), and will then be a sign of ownership to the task. She take 40% of physics talk, this is also a sign of high motivation. Her competence in physics communication is a development for her.

The causal relation for Lena:

**Interest** if she is given time to reflective thinking

→

**Ownership by the CRP:**

Only by the possibility to communicate free (gives possibility to reflective thinking)

→

**Motivation:**

- high competence (highest points in context understanding)
- Lena drives the task (she takes 67% of the planning talk)
- communicate intense with the others,
- high amount of physics talk(40%)
- use of exploratory talks and internal teaching

High motivation

→

**Competence**

Practise her leadership and gets the group into consensus about a correct answers

Development of physics understanding from communicating physics. Also increased social competence by the communication activities.

**Anna** communicates especially well with Lena, and they use exploratory talk to solve the problem. She finds physics difficult but has been successful so far. She has ability to solve the problem, and we see this as an ownership to the task, that gives her high motivation. Her competence is also developed in physics communication.

The causal relation for Anna:

**Interest** in physics but find it difficult and the books boring. Nice with CRP as variation from ordinary teaching.

→

**Ownership by CRP:**

Only by the possibility to communicate free (gives possibility to reflective thinking)

→

**Motivation:**

- high competence
- communicate intense with the others,
- high amount of physics talk(33%)
- use of exploratory talks and internal teaching

High motivation

→ **Competence** as development of physics understanding from communicating physics. Also increased social competence trying to reach consensus

**Kathy** finds physics interesting as long as you keep up with the teacher's speed at lessons. She found the CRP fun, but found it hard to get used to be video-filmed.
She does not say much in the beginning of the session, but when it comes to discuss mathematics her talk will increase. She takes 25% of all talk during session but in the first part she has about 10%, in the second 18% but in the last 35%, when they discuss the mathematical expression. We interpret this as low ownership at start, because the others are faster to find a way to the solution. Her motivation increase when she finds that the others express that all have to agree of the common solution to the problem, and wait for her view. Their internal teaching is crucial for her motivation. This increased motivation gives her also development of understanding, and self-confidence.

The causal relation for Kathy:

**Interest** in physics not that expressed, find it hard if you do not manage to follow the teachers speed.

→

**Ownership at start:** Low ownership as the others are faster then she us to get into the problem.

→

**Motivation:**
- high competence
- communicate with the others when they have used internal teaching and invited her into a discussion to reach consensus in group
- high amount of mathematical talk, need help with algebraic expressions

→

**Competence** as development of conceptual understanding

---

7.3  **Case 6  CRP-The Clay-John-Harry-Agnes**

7.3.1  **Overview of case 6**

**PRIOR**

The three students here called John, Harry and Agnes are low performers in physics class. They find physics boring and demanding, and are quite critical to physics in school. Before they start this CRP session two of them joined a physics test, and answered questions about school physics. This will be their second meeting with our research team, and they are quits excited over the video film camera, and of being put into different group rooms. Initially we did not interfere with the structure of the groups, even if the Minnesota University reports from CRP stressed the importance of a mixture of abilities in the CRP groups. With no high performing members the progress can not be expected to be that high. We find it interesting to see what will happen during work.

**DURING**

They start at once by reading the text, and they follow the time line givenbelow. They are very excited by the video-camera and have some problem to focus on the task.

Time-line

Identify the problem-Variation in the idea of what the problem is

John:       We need…but we don’t have any numbers…
John finds that this is not a common physics problem. He finds no numbers to build problem solving on.

**Problem solving strategy**

John: The thing we need to do is make it 4 times longer, or twice as wide and twice as long.

Harry: I don’t think so… I swear… it won’t work…

John continues to search for a solution. He inclines towards seeing it as a wire that increase resistance with length, but do a mistake about the effect of changing the cross-section. Harry does not follow John's argument at all. He has no physics arguments at all.

**Solve the problem**

John: Shows preposition. We think that as the clay gets longer the resistance increases.

John is already at the result report. Now Agnes shows that she has found something is wrong.

**Reflect over the result**

John: Shows. We think that as the clay get longer the resistance increases.

Agnes: But it is not 1 kΩ either. If it is twice as long then it becomes 500 Ω and not 1 kΩ.

John: No, but we made it 4 times as long.

Harry: (laughing)

Agnes: This just doesn’t seem right. It just can’t be right.

They end the task without a final agreement of the solution. Agnes goes into another group and ask them about their solution. She reports the others solution instead of their own.

**The CRP problem solving timeline**

<table>
<thead>
<tr>
<th><strong>Kategorier</strong></th>
<th><strong>Time</strong></th>
<th><strong>Individuals</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Insight: R increase with increased l</td>
<td>1.06</td>
<td>John: The thing we need to do is make it 4 times longer, or twice as wide and twice as long.</td>
</tr>
<tr>
<td>Insight: R change(decrease) with increased A (?)</td>
<td>2.30</td>
<td>Harry: Will we get the right resistance if you make it twice as long? Will it fit into the holder?</td>
</tr>
<tr>
<td></td>
<td>3.03</td>
<td>Agnes: Do you think it makes a difference?</td>
</tr>
<tr>
<td></td>
<td>3.16</td>
<td>John: But it will be thinner too.</td>
</tr>
<tr>
<td></td>
<td>3.21</td>
<td>Agnes: It doesn’t matter.</td>
</tr>
<tr>
<td></td>
<td>5.26</td>
<td>John: We think that the longer the clay is the more the resistance will increase.</td>
</tr>
<tr>
<td></td>
<td>5.34</td>
<td>Agnes: If it is twice as long then it becomes 500 Ω and not 1k Ω.</td>
</tr>
<tr>
<td></td>
<td>5.44</td>
<td>John: No, but we are making it 4 times longer.</td>
</tr>
</tbody>
</table>

**OUTCOME**

Their presentation of their result does not give the same answer as their discussion. Agnes did changes in hope to improve their result.
7.3.2 Group analysis - results

PRIOR

**I Ownership in setting:**
The task is the same for all groups that give low ownership to the question. This is an experience that to get more ownership to the group is it easy to give different problems instead. To work in small group to solve a problem gives high ownership to the group. They are free to interpret the task in their own way, but as it is an optimal solution there is a risk that low performers do not see the problem, in fact find different view of what the problem is. If this comes to a fruitful discussion it could help group members to insights about physics problem solving

**II Interest in physics:**

(1) Harry said that physics was easy and nice in secondary school, but became very hard in upper secondary school. As he never understood anything it became dull and uninteresting to him.

(2) John said also that physics in secondary school was very interesting and fun, but in upper secondary school he find it very dull. He immediately found himself left behind, and he think that was because of that he did not understand the teachers explanations and that everything was to quick for him.

**III Interest in CRP:** (from Evaluation)

(3) Really fun. The modelling clay was the most fun. The other assignment had too many words. It was hard. (John)

(4) It was fun, but a little hard. (Harry)

**IV Competence:**
The physics test with five questions in formula calculations, five in conceptual understanding, and five in holistic understanding could give maximum (5,5,5) points. Harry (1,1,2), John (1,1,2), Agnes (not present)
The competence test says that this can be a low performing group.

**During:**

**V Communication:**

We find no sign of internal teaching. There is some exploratory talk between John and Agnes. the conversation is complicated, in fact John makes two different conversations at the same time with Harry and Agnes.

(5) Harry: What do you think?
John: I don’t think it will work.
Harry: Will we get the right resistance if you make it twice as long? If you do that it won’t fit in the holder. It fits in the holder but…
John: If that one there is your modelling clay, then that one is the clay thing, if you, like, Flatten it then…and if you role it.
Agnes: So it would be twice as long. Will the resistance be twice as large? If it is twice as long? So it would be twice as long.
John: I don’t think it…(points to her book) Look, this is what they look like…This is what a resister looks like.
Agnes: Do you think it matters?
Harry: But they usually put a line on the last part. If it long there should be a lot more lines right?
Agnes: That is what I have been saying.
John: But is would be thinner too.
Agnes: It really doesn’t matter.
John: (shrugs his shoulders)
Harry: really?
John: Well of course it will.

Communication content:
Amount of talk divided into categories

<table>
<thead>
<tr>
<th>Individual talk divided in categories</th>
<th>Harry</th>
<th>John</th>
<th>Agnes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics and concepts</td>
<td>46/113=0.41 41%</td>
<td>95/158=0.60 60%</td>
<td>54/129=0.42 42%</td>
</tr>
<tr>
<td>Planning and results</td>
<td>22/113=0.20 20%</td>
<td>23/158=0.15 15%</td>
<td>9/129=0.07 7%</td>
</tr>
<tr>
<td>Talk not concerning the task</td>
<td>45/113=0.40 40%</td>
<td>40/158=0.25 25%</td>
<td>70/129=0.54 54%</td>
</tr>
</tbody>
</table>

Table 7.2: Amount of individual talk divided in categories. (% of talk in category)

We divided the talk into the three categories Physics, Planning and results, and Non-task talk and the group did 49% in physics talk, 14% talk in result and planning and finally 35% in non-task talk.

Amount of individual talk in percentage of total talk

<table>
<thead>
<tr>
<th>Amount word</th>
<th>John</th>
<th>Harry</th>
<th>Agnes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>158/400= 40%</td>
<td>113/400= 28%</td>
<td>129/400= 32%</td>
</tr>
</tbody>
</table>

Table 7.3: Percentage of all talk divided on persons

John talks in 40%, Harry in 28% and Agnes in 32% of all the talk. They are equal in the frequencies of the talk.

VI Ownership:
Amount of planning talk:
They did not negotiate much. We saw 14% of planning and result talks. The individual part of this planning talk was John (43%), Harry (41%) and Agnes (17%).

Choice of activities: No special signs

VII Motivation:
Effort: See V Communication.
Persistence: They give 7 minutes to the task.
Amount of physics and concepts talk of total talk:
From the analyses of the amount of individual talk divided into categories we find: John use 60% of his talk to physics talk, compared to Agnes who talk physics to 42% and Harry in 41%.
Outcome:

**IX Quality of work:**

**Amount of work:** They put in a low amount of work in this task when they only spend 8 minutes to try to solve it. They are not eager to check the how likely they are to get a correct answer. But in fact they talk physics at a high amount during work.

Development of competence: They train in talking physics and expressing themselves in a scientific talk.

Development of ownership: They drive the question forward even if they do not reach the optimal answer.

**X Quality of output:**

Products:
Report: Poor; Physics: Poor; Amount of work: Low; Design: Poor.

### 7.3.3 Summary

**Interest in physics**

They all express that they do not catch up with physics teaching. The speed is too high, and to never understand make the subject physics dull and uninteresting to them. They feel frustration with the situation, and long for help. Harry say that his stomach hurts again.

**Ownership at start**

The task is the same for all groups, which give low ownership to the question. To work in small group to solve a problem gives high ownership to the group. They are free to interpret the task in their own way, but as it is an optimal solution there is a risk that low performers do not see the problem, in fact they find different view of what the problem is.

**Competence**

The competence test says that this can be a low performing group.

**Communication**

We find no sign of internal teaching. There is some exploratory talk between John and Agnes. The conversation is complicated; in fact John makes two different
conversations at the same time with Harry and Agnes. John talks in 40%, Harry in 28% and Agnes in 32% of all the talk. They are equal in the frequencies of the talk. We divided the talk into the three categories Physics, Planning and results, and Non-task talk. The group did 49% in physics talk, 14% talk in result and planning and finally 35% in non-task talk.

Motivation and ownership during work
We saw 14% of planning and result talks in percentage of all talk. The individual part of this planning talk was John (43%), Harry (41%) and Agnes (17%). The physics talk were 49% of all talk, and the individual parts John (49%), Harry (24%) and Agnes (28%). John is the main character to the problem solving, as he is dominant both in planning and physics talk.

Quality of output
They do not solve the problem, but they are on the way. In the situation the teacher had no chance to help them during this short period, but they needed some to better call in question the results. It became to easy to give up for the group. their final report gave another answer than the group decided. This showed how important the answer was to Agnes. She felt their own result was wrong, so than she find it better to take the other the answer of the other group. This is an action of low self-confidence. What is positive is the great amount of physics taking during work.
7.3.4 Discussion about evidence

**Fig. 7.7**: Summary of variables in Case 6 “The Clay”- group John, Harry and Agnes.

**John** uses 75% of his talk to the task, and is definitively the group leader. Agnes selects him as secretary to the group. (She takes this back at the end, when she prefers to change the answer!) John finds the problem to be solved qualitatively by reasoning. He has insight in resistance changing with length and cross section area, but are not able to find the algebraic expression to this.

(#{5})

John: We think that the longer the clay the greater the resistance. No, but we will make it twice as long and twice as wide. But it will also be thinner.
The causal relation for John:
Interest Find CRP interesting and fun. (evaluation)
→
Ownership The design gives group high ownership. He interpret the task correctly, that gives him high individual ownership an initiative to drive the problem solving.
→
Motivation He take a great deal of the physics talk (49%) and the planning talk (43%). That is high motivation. He do not show persistence to the task, they end without a correct solution. That decrease the grade of motivation.
→
Competence as development of conceptual understanding: His double conversation concern two different issues: what has impact on resistance, and what is a resistor and how it is reproduced in pictures in textbooks? These strengthen both his conceptual and holistic understanding. He also by his informal leadership gets training into social competence and strengthens his self-confidence.

Harry uses 60% of his talk to the task. He does a lot of chattering with Agnes as well. He is not focused, and he is disturbed by the camera and the odd situation. He does not find the task as a mathematical problem, more like a situations to reach consensus about.
(6)
Harry: Will we get the right resistance if you make it twice as long? It won’t fit in the holder.
I don’t think it is…I swear…it won’t work…What do you think?

The causal relation for Harry:
Interest Find CRP interesting and fun, but difficult. (evaluation)
→
Ownership The design gives group high ownership. He interprets the task incorrectly, that gives him low individual ownership at start. In fact it seems as he do not see this as a physics problem with a mathematical solution, he only express his view and opinion about a result.
→
Motivation He takes part in the physics talk (24%) and the planning talk (41%) (in percentage of all talk), but he also spend 32% of the group talk to non-task chatter, that is 40% of his own talk. He does not show persistence to the task, they end without a correct solution. That decreases the grade of motivation.
→
Competence as development of conceptual understanding: He discusses how textbooks show resistors, and show sign of understanding what a resistor can be at end.

Agnes talks physics in 42% of her total talk, but she only take 7% of the planning talk. As much as 54% she uses as conversation in non-task talk. She is not focused and is overexcited with the video camera. She meets Johns physics talk with an adequate argument. She finds the problem as a mathematical problem that could be solved step-by-step by mathematics:
(#(5))
Agnes: …so it will be twice as long. Will the resistance be twice as large then? If it is twice as long?
   Do you think it makes a difference? But it won’t be 1 kΩ.
The causal relation for Agnes:

<table>
<thead>
<tr>
<th>Interest</th>
<th>Ownership</th>
<th>Motivation</th>
<th>Competence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The design gives group high ownership. She asks relevant questions to John, but gives him the leadership, without reason, because she understand well the problem.</td>
<td>She takes a great deal of the physics talk (28%) but takes not initiative to drive the question forward. She has no persistence to the task, they end without a correct solution. That decrease the grade of motivation.</td>
<td>The low motivation (persistence) gives no chance for development of competence, but at least she starts to talk physics.</td>
</tr>
</tbody>
</table>

To this group it had been necessary with more input from the teacher to get forward. John is given the leadership, but no exploratory talk to get deeper into the problem.

Chapter 8 Comparison between groups

8.1 Differences and similarities

SOL is basically given to the group by the design of the task. If the group themselves can decide the content, the performance, the level of results and sort of presentation and report, then the group has ownership of the task. Many instructional strategies can live up to this and every teacher is able to find his/her own version of this kind of problem based activities. MPs are one example.

If the student can choose a unique question or inquiry from experience in some special situation that he/she remembers as an interesting or problematic issue, the student gets personal or individual ownership to drive the task forward. This was the case when, for example, Mattias asked himself why the transformer became hot without load on the secondary side after his son's accident or when The Electric Motor Group wanted to be able to build an electric motor as they had never done that as girls.

To compare what happened in CRPs and MPs, the main difference is that in CRPs they were forced to use mathematical problem solving, and as much as 40% of their talk included mathematics. When they were free to choose they never chose an MP that contained mathematical problem solving. This we interpret in two ways: There is a need for a more holistic understanding of physics. Not even student teachers have common knowledge about natural phenomena and technical applications and they need practical laboratory work. If they are free to choose, their need for holistic understanding drives them to choose MP of that kind. A disadvantage with MP was that they avoided mathematics, but strength was the improvement of their holistic view. CRPs did not give the group the possibility to choose. But we found that the main problem was in the low performing group to even realise that it was a mathematical problem (John, Agnes, Harry) and if they did (Lena, Anna, Kristin) the algebra became the difficulty that needed time to discuss. Here CRPs became useful for training both with internal teaching and with exploratory talks, and in a more normal situation, than we had in upper secondary school, the teacher will have many more opportunities to help at the right moment. The similarities between MP and CRP
were the freedom for the group to communicate, and we found this to be the key to development of understanding. In MP the longer time to work with the issue, gave more opportunities to exploratory talks and improvement of understanding. The practical laboratory work in the MPs gave opportunity for practical students to contribute more to the task, and to strengthen their position in the group. Jonas, who contributed to the success for The Transformer Group, did it by his interest in the instruments.

In CRP the groups had limited freedom and ownership from the start. For us it was an observation that we could easily have arranged for more group ownership of different problems by different groups. Individual ownership was not possible to design for but it happened by chance, e.g. Lena and Anna were already interested in resistance as we found out in their MP. The two CRPs that were limited to a lesson of 180 minutes, made the groups very engaged. For the low performance group the CRP was too difficult to solve but their talk included to a large extent physics anyhow. It was a problem that no one in the group was able to grasp the problem solving. Minnesota University recommend groups of three selected with different estimated abilities in problem solving to get optimal results. The groups have to be created in a reflective way. If the group consists of low performing students the teacher has to plan for a lot more interaction with the group, and that is a possibility within this instructional setting, as many groups are very self dependent.

8.2 The same groups in both CRP and MP

Lena, Anna and Kathy show as a group high motivation in both types of activities. The higher SOL that is given by MP compared to CRP did not give any differences in motivation. This group is very motivated in both CRP and MP. Because the MP was carried out during a longer time, their time for reflective talks about physics became more noticeable in MP compared to CRP. They also needed to plan for the MP; that was a reason to special actions that gave high motivation. We find this to be a consequence of SOL given by the MP as an instructional design. During their planning they also got influences to exploratory talks about physics concepts. To reach the conceptual change concerning the concepts current and resistance, they needed the possibility to talk for a long time without interruptions. The same group focused in the CRP instead of the mathematical problem solving. Here we could follow the internal teaching, when Kathy needed help to understand the algebraic notions. With MP no mathematics so ever was discussed. John, Agnes and Harry had problems to solve the CRP, and more help from a teacher could have helped them to get into the problem deeper. They showed low persistence to the task, and they were unsure what the demand upon them was. They showed interest to discuss the problem. When this group worked with their MP, they found themselves in the same situation; it was not obvious to them what to do next, and they needed help from a teacher to proceed. Because of the longer time for the MP, the teacher could catch their situation and offered them qualified help that gave the group possibilities to end the project successfully. They expressed interest and pleasure with the possibility to do practical work.
Chapter 9   Summary

Explore how signs of motivation and ownership are to be seen in small group work in physics with mini project (MP) and context-rich problems (CRP)

Ownership of learning has been defined by Milner-Bolotin as the intersection between personal value, responsibility and the feeling of being in control that a student experiences in student-centred problem-based learning. She found students’ interests prior to the choice of a project topic to be relevant for their motivational orientation, and used mastery goal orientation measured by the achievement goal orientation (AGO) questionnaire as a sign of motivation. She also found that the mastery goal orientation changed during the semester, a fact that indicates that the relationship between interest, ownership and motivation orientation are more complex than she first believed. Savery did not express a definition of ownership of learning but four types of factors were studied, chosen as indicators from a cluster of psychological principles: metacognitive and cognitive, affective, personal and social, and individual factors.

Milner-Bolotin gives recommendations for future research to determine other components than interest, which might have an impact on student ownership of the project and on mastery goal orientation. Savery recommends development of instruments to measure the ownership of learning.

I see student ownership of learning (SOL) as an aspect of student influence on learning, because participation is a condition and prerequisite of learning. It has for a long time been an educational goal to reach an increased student influence in the Swedish upper secondary school. (See 2.2.4)

We investigate students’ ownership of learning in a new type of instruction, where mini project (MP) and context-rich problems (CRP) are used in a traditional teacher-centred physics course at upper secondary school level or in introductory physics courses at teacher education in university. The theoretical basis according to self determination theory (Deci 1991) are autonomy, relatedness and competence as basic human needs, which gives a theoretical background for our main hypothesis that students motivation increases with more student ownership.

To be able to give a more narrow definition of the concept student ownership of learning (SOL), we have used transcripts of video and audio tapes, in which student communications and actions were studied and categorised.

Categorisation of the empirical material has given nine variables, and hypotheses of the relations between the variables have been developed. At the end a model is proposed, where interest and competence before start are related to ownership at start, motivation during the performance and to the development of conceptual and holistic understanding and communication abilities. In this model some aspects of communication are seen as a part of the motivation. Motivation will then be seen as energy put into the task, operationalised by persistence with task, and by effort put in to the task (choice of specific activities as communication or exploratory talks, internal teaching and amount of task-related talk or special actions to go around obstacles). Motivation is by this characterised by equifinality. To operationalise motivation as the choice of a particular action, the persistence with it, and the effort expended on it are given in research literature (Pressick-Kilborn 2003). What I do, is to interpret aspects of communication as special activities. I also found that ownership at start is on group level decided by the design of the task, but on individual level by experience or anomalies that give special interest in some aspect.
of the task that makes it a unique question. This increases motivation and development of competence. Ownership that clearly increases motivation also increases development of competence. In the group the ownership given to the group by the design did not develop the competence of all members of the group but it was a condition needed for individual ownership to occur. Several people in the group could have individual ownership; it is not a question of leadership. When students are motivated they talk physics and they choose activities that drive the task forward. To make motivation operational we used the parameter persistence and by that we mean how much time they spent in school on the task (not only!!), and how fast they give up the task (yes). Their effort to fulfil the task we found in some special activities, such as when Kenneth brought a private transformer to school or when Kristin, in a creative way, asked the others if they couldn't do their presentation as if they were a secondary school-class themselves, playing theatre to us. But it was important that we found that the amount of physics talk and existence of exploratory talks and internal teaching were signs of effort and motivation. We found the variable VI "more ownership during work" belongs to motivation, as it was an initiative to plan for the performance and change what to do. If they care what to do, they are motivated. The plenty of ways to reach the goal we call equifinality. Motivation is a sign of equifinality; the observation that several different ways may exist and are chosen to arrive at the same end state. Quite different systems can produce the same results.

Explore how the communication in the group is related to ownership and motivation. We see aspects of communication as a part of the motivation. As parameters for communication we found the amount of physics talks and planning talk, existence of internal teaching and exploratory talks. The communication with the teachers was often categorised as physics talk, never as exploratory talk. This is explained by Barnes (Barnes 1977), who found exploratory talk as a sign of brain-storming between students that felt secure enough with each other to express their thoughts in a form that is not structured and final. The "final draft" is the version or the result that one will present to the teacher. (See 2.34. and 2.4.5) We see exploratory talk as a way towards development of competence, even a condition to learning. To get ownership of learning is to get possibility by the instructional design to use these forms of communications during the physics course. The special actions and efforts that are included in motivation often are seen as aspects of communication.

Define the concept student ownership of learning (SOL), give examples and classify them. Students’ ownership of learning is the student influence/impact affecting tasks and the learning environment in such a way that the student has a real opportunity to achieve physics learning. The task will give the student opportunity to select the task and inquiries, to choose the level of results, method of working and performance, presentation and report. The group composition has to be made in a reflective way when the teacher knows the learners. The expected results will depend on the extent to which feed-back is possible inside the group and by the teacher. Student ownership of learning (SOL) is defined on two levels:
Group level
At the start of a task the student ownership of learning (SOL) is determined by the design of the task. The choice of task, the performance (when, how, where), the level of results and presentation and report can be determined by the students themselves as a group. They choose the miniproject themselves. The performance is decided by them. The decision to go on with the search for energy losses in the Transformer Group and their decision to go on with a Power Point Presentation were their own choices. The Electric Motor Group made clear decisions of time spent for making the motor model, and of content in presentation. The Electric Circuits Group decided to use the analogy with crocodiles to build on, that gave the group a reason to reflective talks about the physics concepts, which they had expressed the lack of in the initial talks. The Electromagnet Group needed help with the strategy, but they talked to the teacher and got the adequate help to finally solve their task. The level of results and presentation and report are decided after negotiations in the groups.

Individual level
A person’s experiences and anomalies of understanding have created unique questions that can create certain aspects of the task that drive this person to be very active and highly motivated. This gives the person a high individual student ownership of learning.
Mattias (in case 1) has a special kind of ownership from the beginning and this can be seen as a cause for his special motivation to do certain actions.
We look at first to his individual ownership. In the initial talks before they decided their final mini project (MP), Mattias talks about his son’s experience with a transformer. In the development of the whole miniproject it turns out that this ownership of a special direction of content and question can be seen several times (for evidence: see p.). This is supported by the fact that Mattias in the preliminary questionnaire gave the highest rank 6 only to the transformer miniproject. During the work, Mattias develops the question why transformers get hot even without load on the secondary side. From this question, he decides to measure the energy losses together with Jonas. They find no sign at first. Mattias believes in the hypotheses and he doesn’t give up. He finally takes the instrument home with him. From a theoretical perspective, this can be seen as three evidences for motivation (see 2.4.1) the choice of a specific action (measurement), the persistence with it overcoming obstacles (does not give up) and even equifinality (taking the instrument home).
Next example is from The Electric Motor Group.
Eva (in case 2) has a special kind of ownership from the beginning and this can be seen as a cause for her special motivation to do certain actions.
In the initial talks she searches for a practical task that is useful for her in her future as a teacher. She has worked as a welder for a while, and she likes to do practical labwork and has self-confidence in solving practical problems. She takes the opportunity to choose a task that is useful to her, and in line with her wish to build an electric motor, which is a task that she never has done before. She is dominant in the group when it comes to the practical work with the motor model. She shows motivation by her purposefulness to make the motor rotate; she does a lot of trouble-shooting, searching for voltage in the circuits at several times. She gives the others instructions and critics. She tries to explain the function to pupils that visit us during lessons.
Lena (in case 3) has a special kind of ownership from the beginning and this can be seen as a cause for her special motivation to do certain actions. She finds physics interesting, but longs for reflective talking over physics problems, as we found in the initial talks and drawings. She inspires others to discuss the concepts of resistance and current by their common analogy of crocodiles. She works for consensus in the group that is important for her. She chooses the role of the teacher in the presentation, to get the opportunity to explain to others her view of physics concepts.

John (in case 4) has a special kind of ownership from the beginning and this can be seen as a cause for her special motivation to do certain actions. John has experiences of electromagnets which strengthen his self-confidence to choose this project. He takes initiative to the electromagnet design, and when it goes wrong, he discusses with the teacher and does corrections that make it to function. He finally takes the initiative to measure the strength of the electromagnet by the evaluation of how many paperclips the electromagnet is able to carry. He shows persistence with the task (how), and is dominant both in process and presentation.

Develop hypotheses concerning the relationship between ownership, motivation and aspects of development of competence.

The model ownership->motivation->development of competence

We propose a model of a causal relation between ownership, motivation and development of competence.

<table>
<thead>
<tr>
<th>Ownership</th>
<th>given by design of the task at group level and at individual level as a unique question that emerges from student experiences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motivation</td>
<td>by effort seen as communication (exploratory talks, internal teaching, amount of physics talk, special actions and amount of planning talk) and as persistence (amount of work, time spent) and results made by equifinality</td>
</tr>
<tr>
<td>Competence</td>
<td>as development of conceptual understanding, holistic understanding, and communicative ability.</td>
</tr>
</tbody>
</table>

The hypothetical model

More **ownership** results in more **motivation** results in more **competence**.

Examples

1: Mattias had individual ownership to the transformer mini project (MP) (see 9.1 and 5.2) This gave him high motivation (see 9.1) He also developed his physics competence by developing his conceptual understanding (seen in the presentation, when he talked about magnetic hysteresis as a reason to energy losses), his holistic understanding (seen in the presentation when he talked about transformers in society with health effects and economical effect for the individual). Finally his competence in aspect of ability to talk physics was trained during the project, and he could communicate with Jonas good enough to fulfil the hypotheses by energy losses and reach results.
2: Lena and Anna both have got individual ownership by their interest in the resistance phenomena, and their experience of an analogy (see 9.1 and 7.2). This gave them high motivation during work (see 6.2). In their MP work they finally went through a conceptual change in their view of resistance and current as they realised the initial standpoint to hold anomalies of understanding. (From charges to get consumed to charges with changing speed). This is development of their competence. Another improvement in their competence is their reflective talks about physics.

3: Lena and Anna had (by chance) individual ownership by their interest in the resistance phenomena when they solved the first context-rich problems (CRP). They also got ownership by their mathematical ability. This gave them high motivation (see 7.2) and they improved their competence by communication about problem solving and algebraic representation of physical quantities.

In conclusion
I have not been able to evaluate the students’ mastery of instruments and laboratory skill, due to the fact that some groups are tape-recorded and not video-filmed. I have only given notes from some groups of the self-evidence and self-esteem that I needed for closer connections to the self determination theory (SDT).

When context-rich problems (CRP) are compared to mini projects (MP), we see how CRP helps students to deal with mathematical problem solving. With mini projects (MP) their individual interest and individual ownership are of more importance, and students’ choices of activities help them to develop a better understanding of physics, sometimes conceptual and sometimes holistic. A way to combine these advantages is to use different context-rich problems (CRP) for the class to choose from. This could give both individual ownership to a unique question and a focus on mathematical problem solving. CRP is easier to manage in a traditional classroom situation, but mini project (MP) give students more freedom to act and create solutions they have interest in.

Evaluation of instruments
In this exploratory study I have developed miniprojects (see appendix 4) and context-rich problems for use in the studies (see Chapter 7.1). I have also tested and developed empirical instruments. In the first study I used a “Perry-test” constructed to find the students’ epistemological view of physics laboratory work compared with there view of small group work in general, and a difference was found that showed how students had a more mature attitude towards general questions then towards physics laboratory work (Enghag 2003). For the second and the third study a competence pre-test with 3 dimensions (mathematical formula calculations, conceptual understanding and contextual understanding) was used and a competence profile established for students (see appendix 5.) A test for the interest of the miniprojects was developed based on a Likert scale (see appendix 6 and Chapter 5.1 and 6.1). The Ownership Measurement Questionnaire developed by Milner-Bolotin was translated (Milner-Bolotin 2001) and used together with an own questionnaire concerning expectations on motivation and ownership, and results were reported to the ESERA conference 2003. (Enghag 2003) Group discussions concerning 5 questions were tape-recorded initially (see appendix 7) and video recordings and transcripts were used to analyse the explored variables.
From transcriptions and tapes the students’ contributions to talk were counted and different types of communication were analysed, e.g. exploratory talks and internal teaching.

Chapter 10 A Final discussion

10.1 An emerging model of causal relations

<table>
<thead>
<tr>
<th>OWNERSHIP</th>
<th>MOTIVATION</th>
<th>COMPETENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group level:</strong></td>
<td>- Effort: Students decide what they bring to the task, choice of special activities, e.g. Exploratory talks Internal teaching Amount of physics talk and planning talk, but also creative actions as bringing artefacts into laboratory or arranging the presentation in a special way</td>
<td>- Development of: - conceptual understanding of physics e.g. conceptual change or finding new concepts and insights - holistic understanding of physics (i.e. understanding of technical applications and nature phenomena) - competence to communicate science - technical skill and instrumental mastering (not evaluated in the study) - self-confidence and self-esteem by experience of own abilities and letdowns</td>
</tr>
<tr>
<td>Choice of: content, question (unique) Possibility to make plans: about performance, level of results, presentation, product Time for: negotiations and reflections</td>
<td>- Persistence: Students decide time spent on a task - Equifinality: many ways to go</td>
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<tr>
<td><strong>Individual level:</strong></td>
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<td></td>
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<tr>
<td>A person’s experiences and anomalies of understanding have created unique questions that drive this person to be very active and highly motivated.</td>
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</table>

Figure: The model of ownership, motivation and competence.

When students get the opportunity to manage their own learning and studying by open-ended tasks in physics, without the teacher determining all details of the performance, this gives more ownership of learning. Two specific ways to give students more ownership of their learning within a traditional teaching approach are to give students "context-rich problems" (CRPs) or "mini-projects" (MPs). The advantage of MPs and CRPs from the student’s point of view is more freedom to act, think and discuss and from the teacher’s view, to get insights of the students’ ability.
and how they really think in physics by more opportunities to observations. As a consequence, the role of the teacher is more of a coach and a tutor and less of a lecturer. But when it comes to delivering a lecture in this new context, the students will give more attention knowing that it will be their own responsibility to come up with results in the coming tasks. We find that ownership is crucial for motivation and development of competence.

Students’ ownership of learning is the student influence/impact to affect tasks and the learning environment in such a way that the student has a real opportunity to achieve learning of physics.

The task will give the student an opportunity to select the task and inquires, to choose the level of results, method of working and performance, presentation and report. The group composition has to be made in a reflective way when the teacher knows the learners. The expected results will depend on the possibility use feed-back inside the group and by the teacher.

Students’ ownership of learning (SOL) we find to be described at two levels:

**Group level:**  
At the start of a task the SOL is determined by the design of the task. The choice of task, the performance (when, how, where), the level of result and presentation and report have to be determined by the students themselves.

**Individual level:**  
A person’s experiences and anomalies of understanding have created unique questions that can create certain aspects of the task that drive this person to be very active and highly motivated. This gives the person a high individual ownership.

We find emergence of hypotheses concerning the relation between ownership and motivation and we see some evidence in the cases reported in this thesis. The ownership as choice of question, possibility to plan for the task and with time for communication has positive effects on motivation can be seen in many ways:

- They make effort in the task by input of ideas, artefacts, questions and suggestions
- They show persistence by spending a lot of time on the task, also by home work. If a person meets an obstacle and does not give up but looks for another "path" to reach the same goal.
- They use exploratory talks, internal teaching and negotiations to reach understanding.

When ownership has positive effect of motivation, an increase in competence follow seen as development of:

- conceptual understanding of physics
- holistic understanding of physics
- self-confidence and self-esteem
- competence to communicate science

We find this model as a hypothesis of the relation between ownership, motivation and development of competence:
Ownership of learning is given by design of the task at group level, and at individual level as a unique question that emerges from student experiences, and

Motivation by effort seen as exploratory talks, internal teaching, amount of physics talk, special actions and amount of planning talk and special actions, and as persistence (amount of work, time spent) and achievements (results made by equifinality)

Competence as development of conceptual understanding, holistic understanding, communicative ability.

The hypothetical model
More ownership results in more motivation results in more competence.

Ownership related to the self-determination theory
Ownership is found to be related to the self-determination theory but also to the theories about student influence. Deci & Ryan found the three basic human needs (Ryan 2000) as the basis for self-determination theory - the needs for competence, relatedness and autonomy.

These three needs are important for people's well-being and function in society. STD searches for people's intrinsic motivation, which is the student’s tendency towards learning and creativity. Secondly their self-regulation is analysed; that is how people transform social norms and extrinsic circumstances into personal values and motivation. As a third step people's impact on factors concerning their health and well-being. It seems to us that our concept SOL is a way of paying attention to how instructional design becomes important to support these three human needs -the needs for competence, relatedness and autonomy. If a group has got ownership from the instructional design, and if an individual has learner ownership by the possibility to relate to experiences and anomalies from earlier, all three needs are addressed. The reason why ownership increases motivation could be this satisfaction of basic needs. We venture to say that that increased interest in giving ownership for students at school will increase motivation and learning due to the fact that ownership gives students satisfaction in their needs for competence, relatedness and autonomy. We find in the cases of The Transformer Group, The Electric Motor Group and The Electric Circuits Group and The Electromagnet Group some evidence of how interest and competence at the start together with group ownership of the task and individual ownership of a unique question within the task make students motivated and increase their competence. The conclusions we draw from our observations are confirmed by what we find to be the argument stepping-stones in the self-determination theory, which we find as an argument for the concept learner ownership to be plausible.

By the concept of ownership we also want to contribute to the public debate on student influence. Student influence is often seen in the light of formal government regulation but we agree with Eva Forsberg (2000) who proposes "to take forward the implications of understanding student influence as a power.”

The connections between student influence and student learning have to include the concept of student ownership. Student ownership has a political aspect that is not touched upon in this study. But student influence of the activities and of the possibilities to realise learning are sharpened by the concept ownership.
Many students feel they want nothing more than to learn but they meet with disappointments as they cannot keep up with the speed and demands upon them. As physics teacher you feel the time pressure to complete the course but also that the efficiency of traditional teaching is low. To include more student ownership of learning is a way to contribute to learning of science. To meet the future this more humble attitude towards the student’s needs could be a way that helps students find science relevant to them.

Chapter 11 Implications to research

11.1 Autonomy supportive vs. - controlling teachers
To continue the research we propose further studies of how autonomy-supportive teachers vs. controlling teachers have impact on students’ ownership of learning. How do autonomy-supportive teachers give ownership to students? How do these teachers teach? STD questionnaires could be used to investigate teachers’ attitudes towards students and this could be related to students ownership observed at group and individual level.

11.2 Environmental physics into MP and CRP
We also want to study how the content of environmental physics affects how relevant student learners and students find physics. Environmental physics includes all introductory physics and we expect students' interest to increase with usefulness and relevance to questions of the future of society. Creating teaching material could also be a contribution to teaching resources as well as to research.

11.3 Small groups as Self-organisation in systems
The phenomena of equifinality in motivation makes it logical to also connect to research in learning as a participation in autocatakinetic systems.(Barab 1999). It could be possible to see the relation between ownership, motivation and competence as a system of feedback coupling. To find methods to study this is a challenge.

Fig.11.1 Hypothetical model of ownership-motivation-competence as a system of feedback coupling.
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Lindman, K. F. D. r. (1917). Lärobok- och övningsbok i Fysik för mellanskolor och seminarier, Söderström& Co Förlagsaktiebolag Helsingfors.


APPENDIX 1 Upper secondary school Physics Curriculum

Aim of the subject

The subject of Physics aims at
1 providing such knowledge and skills as are needed for further studies in natural sciences and technology but also for studies and activities in other areas.
2 The aim is that pupils should experience the joy and intellectual stimulation arising from being able to understand and explain phenomena in the surrounding world.
3 The aim is also to contribute to the pupils' knowledge of natural sciences so that they can take part in public debate on issues related to the natural sciences. This covers analysing and developing their views on questions, which are important for both the individual and society, such as energy and environmental issues as well as ethical issues related to physics, technology and society.
4 The subject also aims at providing advanced knowledge of the role of physics in the development of man's view of the world. Not only has our knowledge of the universe increased --- man has moved from the centre of the world to a planet on the fringes of one of many galaxies in the cosmos --- but our knowledge of microcosms has also increased. In addition, the subject aims at providing increased understanding that theories and models are human conceptual constructions which can be changed in the light of new experience.

Goals to aim for

The school in its teaching of physics should aim to ensure that pupils:
1 have an understanding of the central concepts of physics, quantities and basic models,
2 can speak and write, as well as reflect on the phenomena of physics, its models and concepts,
3 develop their ability to quantitatively and qualitatively describe, analyse and interpret the phenomena and processes of physics in everyday reality, nature, society and vocational life,
4 develop their ability to propose, plan and carry out experiments to investigate different phenomena, as well as describe and interpret what is happening when using the concepts and models of physics,
5 develop their ability with the help of modern technical aids to compile and analyse data, as well as simulate the phenomena and processes of physics,
6 acquire knowledge of the development of the history of ideas concerning physics, and how this has influenced man's world view and the development of society,
7 develop the ability to analyse and evaluate the role of physics in society.
APPENDIX 2 Design and implementation  
Study II: MP in Electromagnetism for Teacher students  12/2002

1: A physics test to give a profile of each person in respect of problem solving ability, conceptual and contextual understanding.

2: Group discussions concerning these questions were tape-recorded:

- 2.1 How do you feel about your time as student in physics in different schools?
- 2.2 What is important to know as a teacher in secondary and upper secondary school?
- 2.3 What expectations do you of working with miniprojects?
- 2.4 Discuss your own suggestions regarding miniproject.
- 2.5 Discuss the list of given miniprojects including your own.

3: Choose a miniproject individually.
4: Give a value in a Likert scale for each project.
5: Questionnaire (Enghag) concerning expectations on motivation and ownership.
6: Tape recordings of the MP group work. One group was also video filmed.

7: The presentations on video film. PowerPoint presentations as artefacts

8: The (Pilot) Ownership Measurement Questionnaire (Milner-Bolotin)

INSTRUMENTS  Study II: MP in Electromagnetism for student teachers  
12/2002

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<th>Purpose:</th>
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<th>Evaluation</th>
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<td>Written test</td>
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<td>Group discussions in three groups (not the MP groups)</td>
<td>View of physics in school</td>
<td>Tape recordings</td>
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<td>Expectations in MP</td>
<td>Tape recordings</td>
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<td>2.4,2.5</td>
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<td>View of the MP</td>
<td>Tape recordings</td>
<td>Transcript</td>
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<td>I-E3</td>
<td>Value of MP</td>
<td>To see what kind of MP different students prefer</td>
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<td>I-5.1</td>
<td>Questionnaire</td>
<td>Expectations on</td>
<td>Likert scale 1-5</td>
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</table>
Study III: MP in Electromagnetism for Upper Secondary School 03/2004

1 Three questions (2003-03-14)
   1.1 Tell me about yourself and how you spend your time, both in your spare time and in school.
   1.2 Tell me about your view of physics in school as you have found it so far.
   1.3 Draw a picture that describes your situation as a student in physics.

2 Competence test (2003-03-14)

3 Context-rich problems (2003-03-21) videofilm and evaluation

4 Group discussions:
   4.1 What expectations do you have in working with miniprojects?
   4.2 Discuss your own suggestions for a miniproject.
   4.3 Discuss the list of given miniprojects including your own.

5 Give a value in a Likert scale for all projects (2003-03-28).

6 Choose a miniproject individually (2003-03-28).

7 Questionnaire (Enghag) concerning expectations on motivation and ownership (2003-03-28).

8 Tape recordings of the MP group work. One group was also video filmed (2003-03-28).

9 Test in physics in ordinary course (2003-04-11).

10 The presentations on video film. PowerPoint presentations (2) as artefacts and reports (2) from four of five groups. 2003-04-23 (after Easter holidays)

11 Ownership questionnaire (Milner-Bolotin) 2003-04-25

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<td>1.2</td>
<td>I-W1.2 Tell me about your view of physics in school as you have found it so far.</td>
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<td>1.3</td>
<td>I-W1.3 Draw a picture that describes your situation as a student in physics.</td>
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<td>3</td>
<td>I-CRPWEN</td>
<td>Video film</td>
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<td>Evaluations of CRP as activity</td>
<td>Questionnaire</td>
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<td>I-W4.1s What expectations do you have in working with MP?</td>
<td>Tape recordings</td>
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<td>4.2</td>
<td>I-W4.2s Discuss your own suggestions for MP</td>
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<td>I-W4.3 Discuss the list of given MPs including your own.</td>
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<td>Likert scale M, O categories</td>
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<td>Choice of MP</td>
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<td>Expectations on motivation and ownership</td>
<td>Likert scale 1-5 in ten questions</td>
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<td>7.2</td>
<td>IW7.2 Questionnaire (Enghag) part 2</td>
<td>Reasons that the group had the initiative to the MP work and to that cooperation worked out well.</td>
<td>Write three reasons</td>
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<td>I-W9 The presentations on video film.</td>
<td>Quality of presentation</td>
<td>PowerPoint presentations or report, video recordings</td>
<td>transcripts</td>
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<td>Quality</td>
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## APPENDIX 3 Category Based Analysis of Video films:
Counting different kind of contributions of students to their talks in group

Description of the categories

**P:** Physics in general as, for example, technical applications in society. If they discuss distribution of electricity to households, they get a mark here.

**E:** Exploratory talks. When students feel safe and interested they help each other using a strange talk, often with half sentences. They search for understanding of a phenomenon and can give ideas as shots in the dark but help each other to get closer and closer to an explanation that both can accept. (Barnes 1976).

**C:** If they use physics concepts such as magnetic field, force, resistance.

**N:** When they talk about instruments and measurements.

**M:** Talk about mathematics and calculations.

**W:** Talk about private matters not related to the MP.

**Pl:** Talk about planning what to do, discuss Excel, PowerPoint presentation etc.

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10
APPENDIX 4 Miniprojects (In Swedish)

MINIPROJEKT 1 ELEKTROMAGNETISK STRÅLNING   Studie 1 2002 vt

I ) Studera ljuset från följande ljuskällor genom ett gitter. Beskriv vad du ser, och förklara m h a dina kunskaper om ljuset som en elektromagnetisk vågrörelse.

A Låga från ett brinnande stearinljus
B Glödlampa
C Ekonomilampa
D Urladdningsrör väte
E Solen ( ej direkt)

II) Välj sedan en laborativ uppgift enligt nedan:
1. **Eget valt miniprojekt**

2. **UV-strålning.**
   Det ultravioletta ljuset gör oss solbrända men kan också vara skadligt för huden med ökad risk för sjukliga hudförändringar. Undersök UV-strålningen utomhus och inomhus med hjälp av mätningar i olika frekvensintervall. Vad menas med UVA UVB och UVC ? Ta redo på fakta kring UV-strålning . Electromagnetic radiation exists in a range of wavelengths, which are delineated into major divisions for our convenience. Ultraviolet B radiation, harmful to living organisms, represents a small portion of the spectrum, from 290 to 320 nanometer wavelengths. (Illustration by Robert Simmon)

   Läs mer: http://earthobservatory.nasa.gov/Library/UVB/

3. **Hur många spår en har CD-skiva?**

4. **Varför lyser glödlampan?**
med Stefan-Boltzmons lag \[ P = \sigma \cdot A \cdot \left( T^4 - T_0^4 \right) \] så att temperaturen kan beräknas. Antag att tråden kan antas stråla som en svart kropp, och att den värme i tråden som leds bort vid kopplingen, samt den strålning som tråden mottar är försämbar. Hela den utvecklade effekten kommer temperaturhöjningen i tråden tillgodo.


Bild: NASA [http://earthobservatory.nasa.gov/Library/SORCE/sorce2.html]

Studera diagrammet ovan och i bifogade diagram hur solstrålningens intensitet beror av våglängden. Observera absorptionen av solljus av vissa frekvenser i atmosfärens nedre skikt.

6 Vad menas med växthuseffekten?
Hur är växthuseffekten relaterad till diagrammet ovan?
Förklara och exemplifiera. Visa i ett experiment vad som avses.

7 Svart eller vit kakelugn.
Vi behöver inte måla värmeelementen svarta, för många vanliga material har emissionstal = absorptionstal = 1,0. Däremot skiljer sig svarta och blanka föremål åt när det gäller att absorbera eller emittera värmestrålning. Visa att det står till på detta sätt. På vilket sätt kan detta sättas i samband med jordens energibalans?

8 Ljusets polarisation.
Vad menas med polarisation? Hur fungerar solglasögon m.a.p polarisation?
Utför följande experiment:

Lampa     Lins     Polarisator     Analysator     Luxmeter

Jämför dina resultat med Malus lag. Vem var Louis Malus?

9 Plancks strålningslag. (Ur Quanta B Ekstig m fl)

Plancks strålningslag kan uttryckas som intensiteten som funktion av våglängden enligt

\[ I_\lambda = \frac{2 \cdot \pi \cdot h \cdot c^2}{\lambda^5 \cdot \left( e^{\frac{hc}{\lambda kT}} - 1 \right)} \]  (W/(m²,µm))

a) Rita upp funktionskurvorna för temperaturerna T=4 000K, T=5000K samt T=6000K och bestäm den våglängd där var och en av kurvorna har sitt maximum. Rita i exempelvis Excel med intervallen

\[ 0,1 \cdot 10^{-6} \leq \lambda \leq 2 \cdot 10^{-6} \text{(m)} \]  samt  \[ 1 \cdot 10^{12} \leq I_\lambda \leq 100 \cdot 10^{12} \text{(W/(m²,µm))} \]

b) Beräkna produkten \( \lambda_{max} \cdot T \) för de tre kurvorna. Testa resultatet för ytterligare en temperaturkurva.

c) Beräkna integralen av funktionen i intervallet \( 0,1 \cdot 10^{-6} \leq \lambda \leq 5 \cdot 10^{-6} \) (m).

Jämför med det värde som fås ur Stefan-Boltzmans lag \[ \frac{P}{A} = \sigma \cdot T^\frac{A}{4} \] (W/m²)
MINIPROJEKT Ellära Studie 2 och 3

Eget formulerat projekt med anknytning till elektriska fält, magnetiska fält, likström, elektriska apparater eller tekniska tillämpningar, elektriska eller magnetiska naturfenomen. (Ett läroboksproblem kan omformuleras till ett laborativt miniprojekt.)

Åskan - ett fenomen i det elektriska fältet kring planeten Tellus. Illustrera och redogör för vad åska och blixturladdning är.

1. Verifiera Coulombs lag experimentellt.

2. Bestäm de elektrostatiska krafterna mellan två laddade ballonger experimentellt.

3. Verifiera kondensatorlagen $Q = CV$ genom att bestärma $C = f(d)$ och $U = f(d)$ när en plattkondensator med variabelt plattavstånd $d$ laddas till en bestämd laddningsmängd $Q$ vid $U = 6,0 \, V$ uppladdningsspänning.

4. Illustrera ett elektriskt rökfilter.

5. Jordens magnetfält – solvinden – van Allen Bälten
   Bestämning av jordmagnetiska fältets horisontalkomposant
   b) Förklara varför jordens magnetfält skyddar oss från solens partikelstrålning
   c) Ge en bild av jordmagnetiska fältets utsträckning
   d) Vad avses med deklination respektive inklination? Ändras dessa med jordens rotation?

6. Häng en kvadratisk spole i en dynamometer enligt figuren nedan.
   Spolen har 50 varv och dess kantlängd är 6,0 cm. Spolens nedersta del befinner sig i ett homogent magnetfält som är vinkelrätt mot spolens plan.
   Strömmen genom spolen kan varieras och du ska bestämma dynamometerutslaget som funktion av strömmen.
   Beräkna den magnetiska flödestätheten i det homogena fältet.

   a) Vad menas med ferromagnetiska respektive paramagnetiska och diamagnetiska material.
b) Bestäm Curietemperaturen för ett material.

8 Illustrera transformatorn och transformera ström och spänning.

9 Tillverka en elmotor och förklara dess funktion.
Linda lackad (varför ?) koppartråd kring ett cylindriskt föremål så att du får en
lindning på ca 10 varv. Ta bort lindningen från föremålet och fäst trådänderna
försiktigt. Lindningen måste vara perfekt jämn för att den ska snurra i balans!
Låt lindningens ändar vara motorns axel. Ena änden skrapas ren från lack.
Andra änden får bara skrapas av på halva sidan längs med tråden. Låt
axlarna vila i gem eller knappnålar som sätts fast på en bit frigolit. Lägg en
stavmagnet under lindningen och anslut batteriet till gemen. Hjälp motorn
igång!

10 En strömförande ledare påverkar vågens utslag- men hur mycket?
Utförande: Placera en hästskomagnet på en känslig våg. Montera upp en sladd
så att den går igenom hästskomagneten. Låt en ström gå genom ledaren. Förutsäg om och hur
vågens utslag kommer att ändras. Kontrollera. Förklara med figur där
strömriktning, riktning på magnetfälten och kraftverkan är utsatta.

11 Tillverka en stark elektromagnet och bestäm dess lyftkraft.

12 Bestäm verkningsgraden för en glödlampa. Hur mycket elektrisk energi
övergår till ljus. Använd specialutrustning

13 Illustrera fältstyrka på två sätt. Dels i en motståndstråd som är kopplad till en
strömåkälla, dels i gapet mellan två kondensatorplattor. Mät och påvisa
spänning mellan två punkter i fältet

14 Använd en kompass för att mäta ström.
Linda tio varv tunn isolerad ledningstråd runt en kompass. Lägg kompassen

15 En fotoblixt hur fungerar den? Ta fram rimliga värden på kapacitans, urladdningstid, spänning och effekt. Illustrera med försök.

16 Du ska förklara och demonstera serie- och parallellkoppling av lampor för en grundskoleklass. Planera och visa dina försök.


18 Att dels beräkna och dels mäta ström samt potential i punkten P när A och B jordas i kretsen.

Måt resistanserna och använd de uppmätta värdena ej märkvarden vid beräkningarna. Beräkna först och kontrollmät sen:

3V

a) strömmen i kretsen
b) potentialen i P när A är jordad,
c) potentialen i P när B är jordad
d) spänningen mellan B och P.

Överensstämmer? Redovisa resultaten.
APPENDIX 5 Competence test

1. En strömkrets är byggd av 14 och 12 V. Bestäm strömströmmen genom lamporna då den ansluts till planken 6 V. Ange det alternativ som är närmast din beräkning:
   a) 3,3 A  
   b) 53 A  
   c) 1,7 A  
   d) 17 A

2. Bestäm total resistansen mellan A och B. Ange det alternativ som är närmast din beräkning:
   A  
   B
   400Ω  
   200Ω
   a) 200Ω  
   b) 600Ω  
   c) 1200Ω  
   d) 10kΩ

3. Våd kronor leder till att anslutna en rök. 1 stinka småpobor under 1 år?
   Spåren har effekten 3,0 kW och effekten är 0,01 kW/Ω. Ange det alternativ som är närmast din beräkning:
   a) 10Ω  
   b) 7Ω  
   c) 14Ω  
   d) 16Ω

4. En fikta anska avskedtar blyset till dockkabeln. Här hör tid ett lampen-lyss för Ölxen och lita på den neder och vänts. Även lamporna är märkta 3 V 0,6 W. Hur mycket tappas lamporna för att spänningsteknik på 12 V enligt figurn.
   Bestäm strömmen som spänningsmätaren levererar när tappet ber på klippa vätska. Ange det alternativ som är närmast din beräkning:
   a) 6,4 A  
   b) 4A  
   c) 1,5 A  
   d) 0,15 A

5. Bäddats i en bil pågår på ett resistansdekk, och en med resistorn 6,0Ω. Täckarna är tagglade enligt figurn. Hur stor är den listas strömströmsresistansen?
   Ange det alternativ som är närmast din beräkning:
   a) 6Ω  
   b) 12Ω  
   c) 6ΩΩ  
   d) 5ΩΩ  
   a) 1,6Ω

6. Tre resistorn är kopplade till en spänningssäkra som figur visar. Resistorn en, R2 och resistorn R3. Vilka av nedanstående städer är korriga?
   a) Spänningsen i AB är större än spänningsen i AC  
   b) Spänningsen i AB är lika med spänningsen i AC  
   c) Spänningsen i EF är större än spänningsen i EF  
   d) Spänningsen i EF är lika med spänningsen i EF  
   e) Spänningsen i EF är mindre än spänningsen i EF

7. En lampa är med en emmersenter och en resistorn ansluten till endast. Emmersenteren, A, visar 0,25 A och emmersenteren A, visar 0,30 A. Vilket alternativ ger den tidigaste förbrinningset av att den värme kan?
   A Enligt förbrinnings  
   B Avtagande temp A, i krönet  
   C A, har större resistans än A  
   D A, har mer mindre resistans än A  
   E Nikom mer av dessa, emmersenterna är likadana.

a) Försök att en amperemeter och en voltmeter.

b) Försök att en amperemeter och en voltmeter.

c) Försök att en amperemeter och en voltmeter.

d) Försök att en amperemeter och en voltmeter.

e) Försök att en amperemeter och en voltmeter.

Fem liknande glödlampor är kopplade enligt figur. Ange vilken av de tre lamporna
A, B och C som lyser stärkt och vilken som lyser svagast.

10. Ett batteri kopplat till tre olika kretsor 1, 2 och 3. På grund av batteriets innebörda

Försök att en amperemeter och en voltmeter.

Försök att en amperemeter och en voltmeter.

Försök att en amperemeter och en voltmeter.

11. Förklara hur ett flottar och vattensn. Rita en krets med batteri och lampa

12. Försök att en amperemeter och en voltmeter.

13. Förklara vad att skicka in.


15. Försök att en amperemeter och en voltmeter. (princip)
APPENDIX 6 Interest in miniprojects- evaluation

<table>
<thead>
<tr>
<th>MINIPROJEKT NR 1 - 20</th>
<th>Motivation</th>
<th>Lärrägande</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- Intresse</td>
<td>- Påverka och kontrollera</td>
</tr>
<tr>
<td></td>
<td>- Nyfikenhet</td>
<td>projektets genomförande.</td>
</tr>
<tr>
<td></td>
<td>- Nöje</td>
<td>- Utvecklande</td>
</tr>
<tr>
<td></td>
<td>- Förväntan</td>
<td>- Givande</td>
</tr>
<tr>
<td></td>
<td>- Allmänt användbart</td>
<td>Möjlighet att uttrycka sina egna tankar och idéer.</td>
</tr>
<tr>
<td></td>
<td>- Tilltro om egen förmåga att klara av projektet</td>
<td>- Ta beslut</td>
</tr>
</tbody>
</table>

Vad får du för uppfattning om miniprojektens? Gradera i skalan 1 till 6, där 1 betyder nej mycket lite, 2 betyder nej ganska lite, 3 betyder nej något lite, 4 betyder ja något lite, 5 ja ganska mycket, 6 ja, väldigt mycket

APPENDIX 7 Questions for Group discussions

Tape-recorded for Study 2.
Förberedelse för arbetet med miniprojekten:

DISKUTERA I GRUPP:
- Hur har du själv upplevt din tid som fysikstuderande på olika skolstadier?
- Vad är viktigt att kunna som fysiklärare på grundskolan respektive gymnasiet?
- Vad väcker beskrivningen av arbetet i miniprojekt för tankar, förväntningar och farhågor hos er med tanke på att ni ska själva nu ska arbeta med miniprojekt?
- Diskutera era egna förslag till miniprojekt och skriv ner frågeställningarna.
- Studera Miniprojekt-listan med samtliga miniprojekt, även era egna. Diskutera och argumentera med de andra.

INDIVIDUELLT:
- Värdera de olika miniprojekten efter de olika kategorierna på blanketten.
- Välj projekt på valblanketten, och motivera noga.