TWO DIMENSIONS OF STUDENT OWNERSHIP OF LEARNING DURING SMALL-GROUP WORK WITH MINIPROJECTS AND CONTEXT RICH PROBLEMS IN PHYSICS

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Abstrakt (svensk version)

Abstract

In this thesis the theoretical framework student ownership of learning (SOL) is developed both theoretically and with qualitative research, based on studies of small-group work in physics with miniprojects and context rich problems. Ownership is finally defined as actions of choice and control, i.e. to realise opportunities to own organisation of the work. The dimension group ownership of learning (SOL-g) refers to the groups’ actions of choice and control of the management of the task: how the task is determined, performed and finally reported. The other dimension, the individual student ownership of learning (SOL-i), refers to the individual student's own question/idea that comes from own experiences, interests, or anomalies of understanding; an idea/question that recurs several times and leads to new insights. From literature and from own data, categories are constructed for group and individual student ownership of learning, which have been iteratively sharpened in order to identify ownership in these two dimensions. As a consequence, the use of the framework student ownership of learning is a way to identify an optimal level of ownership for better learning and higher motivation in physics teaching.

The first part of the thesis gives an overview of the theoretical background to the studies made, and summarises the findings. The second part consists of five articles that report analyses of audio/video-recorded student cooperative work and student group discussions from three collections of data: 1) students working with miniprojects in teacher education, 2) upper secondary school students taking a physics course that includes both context rich problems with group discussions and miniprojects, and 3), aeronautical engineering students working with context rich problems in an introductory physics course at university.

The thesis describes in a fine-grained analysis the conversation in the groups based on Barnes discourse moves, and finds that ownership and communication are related. Group discussions are found to be an indicator for group ownership of learning and exploratory talks often promotes individual student ownership of learning.
Acknowledgements

This project was made possible by the support of many dedicated people. I would like to thank those who shared their ideas and insights on ownership of learning and was co-authors in the papers: Hans Niedderer (my first supervisor), Peter Gustafsson (my second supervisor, head of the department of mathematics and physics at Mälardalen University, leader of our science research group) and Gunnar Jonsson (colleague in physics teaching and science education research and physics research). The work in the project “Context and Conversation in Physics Education” in cooperation with Umeå University with Sylvia Benckert, Sune Pettersson, Ove Johanson, Robert Norman, Peter and Gunnar introduced me into a research community. The fruitful discussions that were of utmost importance for my research education – it was fun, instructive and encouraging to be a member of this research group.

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Thanks to the most important persons in my life, my family: my dad and dear friend, Per Enghag, who has followed my work with interest and encouragement believing in my capacity, and who read the first draft of the cappa, with many useful comments. My beloved mother, who died in June 2006, taught me to call in question what others took for granted—and to follow my heart. I miss you so much! My husband P-O Jungqvist, who desperately wants me to finish this hard work and come back to normal life again—but never, hesitated in supporting my ownership and development—I look forward to the next phase in our life. My children with partners, Hanna, David and Ida, Markus and Sanaz and my grandchild Lea—I wish you ownership to your learning and to your lives. You taught me the most.

The Swedish Graduate School of Science and Technology Education, FontD, has given me financial support. The FontD courses and seminars have been important for my development of the thesis. Thank you Lena Tibell for encouragement in critical periods, your support was very valuable! Thank you all friends at FontD for all the interesting discussions!

This work has also been supported by the Swedish Research Council and the Board of Educational Science at Mälardalen University.
Prologue: Why students do not choose science

Sjøberg (2002) suggests underlying reasons for the present difficulties in recruitment to scientific and technological studies from the perspective of a European country. He argues that there are three causes referring to schools (Sjøberg, 2002):

- outdated and irrelevant curricula
- scientific knowledge as by its nature abstract and theoretical
- a lack of qualified teachers

Within a Swedish perspective Selander (1998) finds that the generally objective for schools has changed. Looking more closely at physics as subject, there has not been a corresponding displacement in the curriculum – science education has succeeded in preserving a strong tradition and strong subject delimitation (Selander, 1998).

Furthermore Sjøberg gives several causes related to wider social trends:

- anti- and quasi-scientific trends and 'alternatives' as ‘new age’
- postmodernist attacks on science and technology
- a stereotypical image of scientists and engineers
- Disagreement among researchers perceived as problematic
- Problematic values and ethos of science
- Many people dislike the image and ambitions of modern biotechnology and have an emotional and irrational fear about scientists who are 'tampering with nature' or 'playing God'.
- The earlier image of the scientist as a dissident or a rebel has been replaced with a less exotic image of a worker loyally serving those in power and authority. The previously privileged perception of the scientist as a neutral defender of objectivity and truth is increasingly being questioned by the media, by many scholars, and by school pupils
- A white-coated, hardworking, and not very well paid, scientist in a laboratory is, therefore, not a role model for many of today’s young people.
- A communication gap between scientists and the 'public'.

An honest and critical look at these arguments makes me convinced that it is not only students in the position of making educational choices who suffer from these influences, but all of us, including physics teacher in schools in their various capacities. At the same time, most of us believe in science as the only possibility to deal with knowledge and problems pertaining to
contemporary life and events. We require building a new picture that inspires confidence in physics and science, and helps young people regarding their relation to science. I am convinced that school teachers are the most important people to realise this through the opportunity they have of meeting students and pupils in open-minded and serious discussion of issues that matter in contemporary life, and by teaching and using scientific argumentation. Physics is important because of its usefulness, its pleasure to study and work with, and urgent necessity in society. Students could identify themselves with physics supporting a society working towards a sustainable development and learn to see physics as a way towards understanding environmental issues and supporting, for example, energy production problems. Students need to feel that they are competent and useful in their contribution towards understanding the planet earth and what is necessary for a safe future. They have to be informed about what physicists do and how the planet is slowly moving towards a flip of the earth’s magnetic field directions, towards a new ice time, as well as the increasing impact on climate both from heating factors from carbon dioxide discharge and cooling factors from increased global haze. Within our high technological society, physics is needed to solve the problems humankind is facing. An understanding of physics, rather than a denial of what physics has to contribute, is necessary. The culture within physics education needs to invite every student to learn more about nature and technology in a respectful manner with the firm conviction that each individual who learns more about physics finds a ways and means to use this in a valuable way for society. To teach physics is not to convince students of the laws of nature but to give an invitation to discussions about how our world functions and to a search for problem solving methods. This modest attitude could be seen as a recover from a long time of growing supercilious attitude of being exponents of the one and only truth associated with military power and economic greed.
1 Introduction

1.1 The aim of this thesis

This thesis aims to study, analyse, and describe student influence to their learning. The focus is on small-group work in physics courses within three educational contexts: a science programme in upper secondary school, a science teacher programme, and an aeronautical engineering programme at university level. The goal is to develop a theoretical framework for student ownership of learning by carrying out a number of case studies of students working in small-groups with two instructional settings, namely, mini-projects and context rich problems. Three areas of significance can be pointed out: firstly, a better understanding of critical aspects of student influence, secondly, to support teachers with some insights into the design of learning tasks that incorporate small-group work in physics, and thirdly, the development of a methodology within which the work will take place. The pedagogical framework is grounded in problem-based learning and inquiry-based learning as a part of traditional physics courses and in cooperative/collaborative learning as problem-solving by context rich problems (developed by the University of Minnesota). The theoretical background for the study is based on earlier studies about ownership of learning within a constructivist perspective (Dudley-Marling & Searle, 1995; Milner-Bolotin, 2001; Savery, 1996) but methods for discourse analyses of the students’ communication are grounded in a socio-cultural perspective (Barnes, 1976; Barnes & Todd, 1977, 1995). The theoretical framework developed is called two dimensions of student ownership of learning and is developed in order to be able to answer the question: How is student ownership of learning seen in the classroom?

The major objectives of this study are, therefore, as follows: (See also Chapter 5, p. 46):

**Objective 1:** Develop theoretically the concept student ownership of learning (SOL) and develop empirically categories which allow us to see SOL in concrete learning and teaching situations.

**Objective 2:** How does the conversation develop during work individually and as discourse?

**Objective 3:** How is ownership and communication related?

The approach to meeting the three objectives outlined above was driven by an interaction between theoretical studies of related literature and empirical studies of small-group work in physics classrooms.
1.2 Contributions

Theoretical

In this thesis, a theoretical framework has been developed in order to analyse student influence with regard to their own learning environment during the physics education. The theoretical framework, student ownership of learning (SOL), can be used as a reflective tool for researchers, teachers, and students in analysing student influence of the science classroom during small group-work. SOL is a theoretical framework by which it is possible to estimate or reflect upon student influence in task performance and moves towards learning in science classrooms during small-group work.

SOL was finally defined as actions of choice and control, and was developed by differentiating the following two dimensions:

1. regarding the group’s influence and actions on the control and choice of the task, the performance, and the presentation.
2. regarding the individual student’s actions and talk-actions of choice and control in the learning process that can be analysed on the basis of their own questions and their own anomalies of understanding.

The concept of ownership is aimed for evaluating and studying instructional settings based on pedagogical concepts to reform physics teaching, for example problem-based learning, inquiry-based learning, mini-projects and context rich problems in which students work in small-groups. How ownership is related to concepts as experience, exploratory talks and mimesis is elucidated.

Empirical

The individual student ownership of learning (SOL-i) is a construct with categories based on positive and negative cases of single students. These categories were iteratively developed and finally checked by interrater reliability calculations. The group student ownership of learning (SOL-g) is a construct with categories based on cases of different mini-projects (MP) and context rich problems (CRP) and on earlier studies of ownership. Conversation analyses are used to explore the students’ conversation during group work with focus on their exploratory talks during work. A categorisation of discourse moves are developed from Barnes and Todd (1977) and visualised by flow charts. Some examples of effects of SOL such as conceptual change, moving from everyday life reasoning to physics reasoning, are
reported. A method development for conversation analyses from time-lines and flowcharts and a revision of Barnes categories for “discourse moves” is done.

The thesis is a contribution to the research aimed at improving the teaching of physics and facilitating students to take part in the community of “naturvetare” natural scientists.
2 Background

My interest in increased student influence began with the effects of my own teaching when I stopped carrying out experimental demonstrations in front of the class in favour of letting small groups of students investigate and perform the experiment themselves. As there was not enough equipment for everyone, the idea of small groups elaborating the demonstration increased to several different simultaneous experimental demonstration stations, with a common summary and evaluation at the end of the lesson. I often used this type of lesson at the stage of the course when a physics area such as, for example, the electromagnetic field, or force and action, had come to an end. I came to appreciate the interesting discussions I got involved in, as well as the interesting contributions from the students. The need for strong management appealed to my long teaching experience, and the fruitful talks increased my own knowledge. Experiences from European school development projects made me see the learning potential when students had opportunity to communicate with a higher degree of freedom around a task or project.

2.1 How my research is situated

2.1.1 The physics community

The physics community has been concerned about the problem of students’ “misconceptions”, or “alternative conceptions”, of basic physics concepts reported from cognitive science and science education research. Physics educators have developed new teaching approaches and tried to disseminate them, for example Mazur (1997), who designed lecture hours where students were active and inter-active solving qualitative questions and developed collaborative learning in large lectures. He found how the traditional presentation was nearly always delivered as a monologue in front of a passive audience. He published concept tests and user manuals for teaching for enhanced physics understanding instead of pure memorisation (Mazur, 1997) but developed towards to incorporate cooperative learning into the discussion sections, as well as the lectures (Crouch & Mazur, 2001). Physics educators emphasised the necessity of group discussions and group work where the teacher was more a discussion partner, in order to promote meaningful understanding of physics problem-solving. Physics problem-solving and the context of the problems themselves also began to come under scrutiny. Physics text-book problems were criticised for being too adapted to formula-thinking and without relevance in the student's life. The University of Minnesota developed also problem solving in the tradition of cooperative learning (Heller & Hollabaugh, 1992;
Heller & Heller, 1997; Heller, Keith, & Anderson, 1992). Umeå University was the first in Sweden to introduce group discussions with Context Rich Problems in their physics courses, influenced by the University of Minnesota (Benckert & Pettersson, 2004), and developed this approach together with physics teachers also for upper secondary school (Benckert, Pettersson, Aasa, Johansson, & Norman, 2005). Since 2002, Mälardalen University has developed mini-projects in physics, and group discussions with context rich problems.

2.1.2 Science Education Research

My view of Science Education Research (SER) is close to the broad description given of the Norwegian researchers Lorenzen, Streilien, Tarrou-Høstmark and Aase (1998):

*All those reflections that can be connected to the teaching of this subject that can give increased knowledge of the character of the subject, of its rationale and increased knowledge of how the subject can be learnt taught and developed. (Lorentzen, Streitlien, Tarrou-Høstmark, & Aase, 1998)*

However, there is still an ongoing tension between subject didactics being regarded as the science of how to teach and learn within the educational paradigm of today, mainly focusing on conceptual understanding within physics theory (Andersson, 2000; Lijnse, 2000) and subject didactics seen from the view of educational science searching for a new paradigm of education (Lemke, 1990, 1994, 2000). This latter view is based on communication. This replaces the view of knowledge and learning as something to acquire with the view of knowing and learning as partnership in an on-going process. A summary of this tension between views of learning is given by the researcher of mathematics didactics, Anna Sfard, in her discussion about learning as the metaphor of acquisition versus the metaphor of participation, and her analysis of the dangers of choosing just one of these (Sfard, 1998). Several conceptual frameworks to view learning as integration with a community had been developed, e.g. the theory of situated cognition (Brown, Collins, & Duguid, 1989) and situated learning as legitimate peripheral participation (Lave, 1988; Lave & Wenger, 1991). It could be a troublesome consequence that the well-defined subject matter in the science or mathematics classroom is disappearing, and the whole process of learning and teaching is in danger of becoming amorphous and losing direction (Sfard, 1998, p. 10). Furthermore, the subject matters themselves can show a fruitful convergence of different subject matter issues into a content that gives broader perspective for better understanding, but this also means a risk for the subject matter to be characterised as eclectic and lacking in depth. A natural
reflection here is of course how much of the content that is relevant for students today, and how much is kept in the courses for reasons such as convention and power and authority. My research contributions are located on the border-line between subject didactics and general educational research. The communicative approach for meaning making of physics introduced by Mortimer and Scott (2003) is very close to my view of an enhanced physics teaching.

When Mortimer and Scott discuss staging the teaching and learning performance (Mortimer & Scott, 2003, p.17), they emphasise the three basic steps for effective teaching and learning: 1) the teacher must make the scientific ideas available on the social plane of the classroom 2) the teacher needs to support students in making sense of, and internalising, those ideas and 3) the teacher needs to support students in applying the scientific ideas, while gradually handing over to the students the responsibility for their use. My work and my investigation of small group work in physics can be seen as situated in their third basic step – how to support students in applying the scientific ideas, while gradually handing over to the students the responsibility for their use. More student influence in the classroom has been realised when more time has been spent on talking physics (Leach & Scott, 2003; Lemke, 1990; Webb & Treagust, 2006) and when students have worked in cooperative groups (Baylon, 2005; Johnson & Johnson, 1974; 1978; 1989; 1991; 1992; 1994; Johnson, Johnson, & Holubec, 1993; Sharan, 1980; Slavin, 1988) or collaborative groups (Stamovlasis, Dimos, & Tsaparlis, 2006). My view is that contemporary physics education has a challenge in how to meet student ownership of learning.

2.1.3 Aspects of Methodology

My view of research methodology is influenced by Max Weber (1864-1920) who has a view of life that can be described as ontological individualism, i.e. everything that exists is of individual nature, and collective phenomena as society, class or group has no independence over individual existence; they are made in the world of ideas.¹ The individuals’ relation to the collective is as important a question nowadays as ever. Situated learning today has been done by describing the collective; how the communication in the group has developed, and how participation in a group activity produces knowledge together with others (Barnes & Todd, 1995).

As a teacher, I look for the individual in the collective, and have an interest in, and concern for, the individual’s exposed position during work. Weber emphasised the fact that it is the individual who acts, but the researcher can contribute with analyses of the consequences of different actions to which the individual is responsible for having an opinion about. Weber’s basic view was that the main aim with research is to contribute with analyses in order to structure the empirical reality and to give increased awareness of the way all actions are an attitude to a set of values. Weber’s arguments for social science research are useful for science education research as well. According to him, the concepts we use to describe reality are constantly changing. How concepts develop depend on how the presentation of a problem is given and this changes in the same way as the culture itself changes.

Weber’s view is that our ideas about the reality transform the reality by all facts we have gathered. The result is a description that corresponds to a time that is already gone. Within science education research, the focus has turned away from how physics concepts are understood and used, towards a focus on the interaction and meaning making that goes on in the classroom or in other institutional learning-situations. At the same time, didactics constitutes the specific scientific domain that studies the learning of the subject matter, or the relation between the students and the subject matter. The schools still use the scientific-rational categorisation in school subjects, but are slowly converting towards a broader view of knowledge. In a time when schools tends to opt for thematic or subject-overarching teaching, the thoughts from Weber about how the research strategy has to change within the culture that changes, become important. Physics, as the theory of matter, is still there to be learnt, but the situation within which the learning process can take place is a changing one, and thereby the research methodology has to be different as well.
3 Pedagogical background

The instructional settings used in these investigations are developed by using 20-25 percent of the physics course time for small-group work based cooperative learning, mini-projects, and group discussions with problem-solving of context rich problems. The study takes departure in a situation where students have been taught physics by lectures and laboratory activities, and where the small-group work of cooperative learning character is included as an activity, by own activity, to increase their physics understanding and meaning making. This activity is influenced by the traditions of problem-and project-based learning (PBL).

3.1 Problem-based and project-based learning

Problem-based learning have been developed from their onset within medicine (Barrows, 1985). Barrows wanted medical students to be able to apply content knowledge in clinical settings through problem-solving. Problem Based Instruction (PBI) was introduced in Sweden’s medical education as a way to promote deep-learning in favour of shallow/surface-learning (Dahlgren, 1998; Marton, Dahlgren, Svensson, & Säljö, 1999). Problem based learning/instruction benefits from the need within meaningful learning to acquire a comprehensive view; the problems that the learner is supposed to work with have to be intelligible to the student. To increase the authenticity of the task the problems would be taken from a relevant real-world context, and without provision of information that a real-world context would not provide. Dahlgren (1998, p.5), emphasises that the complex reality has of course to be studied also in its parts. There has to be an interaction between the parts and the wholeness when studying a phenomenon, but it is important that the student understands the task to be meaningful and useful in society after the studies are completed. However, authenticity is not only a question about the content of the subject matter in the course and the task. Greening, (1998, p.2) reviews and quotes Schmidt (1983) who gives the essential qualities of PBL as activation of prior-learning via the problem, encoding specificity such that the resemblance of the problem to intended application domains facilitates later transfer (leading to an emphasis on authentic learning environments); and elaboration of knowledge via discussion and reflection to consolidate learning experiences. Also the students’ opportunities to develop a more scientific relation to knowledge and learning are likely to increase (Greening, 1998; Schmidt, 1983). Also the students’ opportunities to develop a more
scientific relation to knowledge and learning are likely to increase. Greening, (1998, p.9) also reviews Honebein, Duffy, and Fishman (1991) who identify a number of elements that lends authenticity to a task:

- **Learner ownership**: This is supported by the argument that metacognition is essential to function well in complex environments and therefore the students must be supported in developing a sense of responsibility for their management of problem-solving tasks, which suggests problems ownership.

- **Project-based nature**: This suggests a holistic representation of the task, with opportunities for authentic global (wider context) entities as well as more localised ones.

- **Multiple perspectives**: The empowerment of students to consider multiple perspectives when examining a problem domain is an important mechanism for developing expertise. One of the means for encouraging this is in the use of collaborative learning environments, such as those typically used in PBL programs (Honebein, Duffy, & Fishman, 1991).

The empowerment of students is a factor challenging the structure of traditional education. Dahlgren (1998) describes the examination and review process within PBI not as private, such as in traditional examination forms, but public; other students participate and share the examination session. PBI places demands on the organisation of the subject content, of the students own responsibility to learn, and of the ability for students and teachers to use group work. The effect of the tutor is important in PBL, and the tutor requires to be well placed to provide scaffolding to learners.

The PBL strategy became dominant in education within medicine and spread to other educational areas; at first to economics and computer technology. The three dominating subject matters within science have slowly begun to include PBL in their curriculum, even if resistance towards the influence remains. In Sweden this bears reference to the old division between the university based teaching tradition and the class-teacher based teaching with its roots within “seminarie-traditionen”- the seminary tradition (Carlgren, 1992, p.3). The syllabus for physics in upper secondary school never really did change, – even if the national curriculum since 2000 decrees that teaching should be more learner-centred and holistic in its character. Subsequently, even if Swedish curriculum is influenced by a Dewyian perspective on education, the tradition of upper secondary school teachers and interested persons in
society relying on university tradition and a university view of physics (Enghag, 2004), has slowed down the development towards problem-based learning environments.

In the American National Research Council’s *National Science Educational Standards* (1996), the guidelines for science education emphasise the need for an inquiry-based learning environment whereby students in collaboration can build their scientific understanding by making their own investigations and explanations of phenomena. Since a shift to instruction of this kind makes a radical break with customary teaching and learning in the classroom, different results have been reported and special interest has been on assessment procedures in PBL learning environment (D’Amico, 1999). Portfolio and e-portfolio is becoming an important tool such as, for example, to give weekly feedback about the assignments, to have the opportunity to redesign them before final submission. This has been reported as a great chance for student self-improvement (Gülbahar & Tinmaz, 2006). Within a problem-based learning environment, the established classification and fragmentation of subject matters have loosened up. Knowledge is seen as being created in the process of problem-solving that stimulates understanding and reflective thinking. The character of knowledge is then socially constructed and dependent on time and context. This view of knowledge and learning is a challenge to established education such as influencing the authority and power relations (Silén, 2001, p.33). Students in problem-based learning would tend to see learning and epistemology as flexible entities and would see how there are other valid ways of seeing things besides their own perspective. They would use dialogue and argument as an organising principle in life so that through dialogue they would challenge assumptions, make decisions and rethink goals (Savin-Baden, 1998). From my own personal experience, within problem based learning, I could find some of the ideas I was looking for, but they seemed to be developed either for university courses with high resources and the possibility of having one teacher to every base-group of 8 students, or for elementary schools with other criteria and learning demands. In project-based learning, students work in teams to explore real-world problems and create presentations to share what they have learned. Compared to learning solely from textbooks, this approach has many benefits for students, including deeper knowledge of subject matter, increased self-direction and motivation, and improved research and problem-solving skills. My view is to open this up for more student contribution and promote improved student influence by modifying the instructional settings in the subject matter of physics. Teachers must develop relevant and meaningful problem and learning methods, and empower students with valuable skills (MacKinnon, 1999). When students solve physics problems in groups, or work with projects in physics, they relate to their own
experiences and their own everyday view of the actual physics phenomena involved (Enghag, Gustafsson, & Jonsson, 2006). This is interesting from both a learning perspective and from a teaching perspective. What working conditions during school activities support learning that start from a conversation concerning experiences?

### 3.2 Small-group work within cooperative learning versus small-group work in general

Johnson and Johnson (1994) give five elements necessary for cooperative efforts that are expected to be more productive than competitive and individualistic efforts. See “An overview of cooperative learning”\(^2\) for a detailed description of these conditions. These elements are:

- Clearly perceived positive interdependence
- Face-to-face interaction
- Clearly perceived individual accountability and personal responsibility to achieve the group’s goals
- Frequent use of the relevant interpersonal and small-group skills
- Frequent and regular group processing of current functioning to improve the group’s future effectiveness

Blosser (1992) emphasises the pitfalls reported by Ellis & Whalen (1990) in general forms of small-group works and compares this to the core elements of cooperative learning given above. The teacher responsibilities are of importance here.

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<tr>
<th>“Cooperative” groups</th>
<th>Pitfalls reported in other in small-group work</th>
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<tr>
<td>Positive interdependency “Students sink or swim together”, Face-to-face oral interaction.</td>
<td>No interdependence. Students work on their own, often or occasionally checking their answers with other students.</td>
</tr>
<tr>
<td>Individual accountability: each student must master the material.</td>
<td>Hitchhiking: some students let others do most or all of the work, then copy.</td>
</tr>
<tr>
<td>Teacher monitors of students' behaviour needed for successful group work.</td>
<td>Teacher does not directly observe students' behaviour.</td>
</tr>
<tr>
<td>Teachers teach social skills needed for successful group work</td>
<td>Social skills are not systemically taught.</td>
</tr>
<tr>
<td>Feedback and discussion of students' behaviour is an integral part of ending the activity before moving on.</td>
<td>No discussion of how well students worked together, other than general comments such as &quot;Nice job&quot; or &quot;Next time, try to work more quietly.&quot;</td>
</tr>
</tbody>
</table>

Table 1: Comparison between cooperative learning strategies and general small group work pitfalls.\(^3\)


\(^3\) After Blosser (Blosser, 1992) adapted from (Ellis & Whalén, 1990)
3.2.1 Cooperative learning strategies

Cooperative learning is an instruction method in which students work in groups towards a common academic goal.

*The ability of all students to learn to work cooperatively with others is the keystone to building and maintaining stable marriages, families, careers, and friendships. Being able to perform technical skills, such as reading, speaking, listening, writing, computing, and problem solving, are valuable but of little use if the person cannot apply those skills in cooperative interaction with other people in career, family, and community environments. The most logical way to emphasise the use of students’ knowledge and skills within a cooperative framework, such as they will meet as members of society, is to spend much of the time learning those skills in cooperative relationships with each other (Johnson & Johnson, 1994, p.11)*

Johnson and Johnson (1994) review studies of cooperative learning and summarise how cooperative experiences tend to

- promote greater cognitive and affective perspective taking than do competitive or individualistic learning experiences
- promote creative thinking by increasing the number of ideas, quality of ideas, feelings of stimulation and enjoyment, and originality of expression in creative problem solving
- produce higher levels of self-esteem than do competitive and individualistic efforts

However, problems with implementation due to resistance from teacher and students are also reported. Reasons why teachers do not use collaborative learning techniques are discussed on the listserv on collaborative learning (Panitz, 1996)4

These reasons include:

- teachers’ loss of control in the classroom as well as their lack of a) self confidence, b) prepared materials for use in class, c) familiarity with alternate student assessment techniques, d) teacher training in collaborative teaching methods
- students’ lack of familiarity with collaborative techniques as well as fear of content and ability to achieve high grades

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Many variations of cooperative learning have proven effective in classrooms worldwide, for example Jigsaw, Group Investigation and Context Rich Problems.

### 3.2.2 Cooperative Learning vs. Collaborative Learning

Galvin (1997) defines the difference between cooperative and collaborative learning primarily by whether the assessments are of individual character or if the group is graded as a team. However, both expressions are sometimes used without sharp distinctions (Hammar-Chiriac, 2005).

**Cooperative Learning:** Students are assessed individually within the course. Oftentimes some percentage of the overall grade reflects the individual student’s participation in group projects. Since most instructors can easily include group work and team projects within an established course without much disruption to the syllabus, cooperative learning strategies are the more frequently used form of small group or team process.

**Collaborative Learning:** In a collaborative learning environment, individual performance is de-emphasised, while teamwork is promoted. Groups plan learning activities together, divide tasks among themselves, carry out their action plans, and present a completed project, display or report to the class, and are graded on their work as a team (Galvin, 1997).

Crawford, Krajcik, and Marx (1999), review articles describing different components of the “community of learners in science classrooms”. They distinguish six types of components that are also relevant for student ownership of learning. (See Chapter 4.3).

- Authentic tasks: Instruction is situated in tasks that are based on real world problems.
- Interdependency in small-group work: Group members function by relying on each other to complete a task.
- Negotiation of understanding: Students and teachers debate ideas and negotiate understanding of substantive science content
- Public sharing: Students collaborate with experts outside the classroom community
- Collaboration with experts: Students collaborate with experts outside the classroom
- Shared responsibility: Responsibility for learning and teaching is shared
  (Crawford, Marx, & Krajcik, 1999)

Instructional settings that balance and focus these issues can be of different types: traditional (where instruction is situated in topic areas and aligned with text-books), or intermediate
(where instruction may be relevant to students’ lives but the tasks, however, are determined mainly by the teacher) or constructivist (where students take ownership of the problem area and formulate their own questions). Moreover, the students independency of the teacher is named traditional (maximal teacher guidance), intermediate (ask the teacher frequently), and constructivist (students look to group members instead of the teachers).

With references to this categorisation, miniprojects, MPs, have a constructivist teaching character in all aspects, but context rich problems, CRPs, are of an intermediate character with regard to instructional setting but constructivist concerning independency.

3.2.3 Context rich problems

The context-rich problems used at the University of Minnesota Department of Physics are written as short stories including a reason for calculating a specific quantity and are designed to promote discussion and interaction, thus enhancing learning (Heller & Hollabaugh, 1992; Heller & Heller, 1997; Heller, Keith, & Anderson, 1992). The student is the important person in the story and the text speaks directly to him/her throughout the problem. The way in which a CRP is expressed compared to a traditional text book problem is exemplified below, downloaded from the University of Minnesota.

An example of a traditional problem
Cart A, which is moving with a constant velocity of 3 m/s, has an inelastic collision with cart B, which is initially at rest, as shown in figure 1. After the collision, the carts move together up an inclined plane. Neglecting friction, determine the vertical height h of the carts before they reverse direction. The following context rich problem is the same problem; only it avoids the pitfalls of the traditional problem.

An example of a the Context Rich Problem version
You are helping your friend prepare for her next skate board exhibition. For her programme, she plans to take a running start and then jump onto her heavy duty 15- lb (6.8 kg) stationary skateboard. She and the skateboard will glide in a straight line along a short, level section of track, then up a sloped concrete wall. She wants to reach a height of at least 10 feet (3 m) above where she started before she turns to come back down the slope. She has measured her maximum running speed to safely jump on the skateboard at 7 feet/second (2.1 m/second).

5 UMPERD : http://groups.physics.umn.edu/physed/Research/CRP/crintro.html
She knows you have taken physics, so she wants you to determine if she can carry out her program as planned. She tells you that she weighs 100 lbs (45 kg).

![Diagram](image)

**Figure 1:** Determine the vertical height $h$ of the carts before they reverse direction.

This original ways of constructing a context rich problem gave the following results:

- The problems needs to be sufficiently challenging that a single student cannot solve it but not so challenging that a group cannot solve it.
- The problems need to be structured so that the groups can make decisions on how to proceed with the solution.
- The problems should be relevant to the lives of the students.
- The problems cannot depend on students knowing a trick nor can they be mathematically tedious.

The instructions given from the University of Minnesota of how to construct concept rich problems are detailed:

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

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, the concluding question after a description of a situation may be something like "Will the design work?" or "Do you believe the boy’s story?" These types of statements not only 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 such 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.

Table 2: How to construct a context rich problem. From University of Minnesota

In our research we developed context rich problem as underdetermined problems where the main difficulties were more related to deciding about the missing parameters than to sort out the extra information given. See the paper III, and V.

3.2.4 Miniprojects

A miniproject (MP) is a task or experimental problem/inquiry given in order to increase the competence in physics. The MP could be given in different degrees of freedom, and for different time periods. We used MPs that were completed within approximately 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. The context was preferably related to a real-world problem. The students were put together in groups after they had chosen MPs from a list of MPs made by the teacher. One possibility was a totally free choice of task within the content area. For further details, see Enghag (2004). Some examples of mini-projects chosen:

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6 http://groups.physics.umn.edu/physed/Research/CRP/crintro.html)
• The Thunders – phenomena in the electric field around the Planet Earth.

• Illustrate the transformer and transform voltage and current.

• Handbook for teachers – safety with electricity

• The Earth’s magnetic field – The Solar 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?

• Make an electric motor and explain how it works.

1 Mini-project Task

4 Reflections and new ideas from evaluating what has been done so far

5 Presentation in front of class Written report or PowerPoint presentation

2 Development of the performance/ Ideas for limitations and performance

3 Experiments and calculations, interpretation of results

Figure 2: Mini-project implementation After Enghag, (2004).
4 Theoretical background

The thesis took departure theoretically in the ownership of learning theory developed in literature and mainly based on constructivist learning theory. The methodology, which involves conversation analyses originally grounded in Barnes’ socio-cultural theory, necessitated a developed theoretical framework for the ownership of learning theory that grew to be the main work of the thesis. This is the consequence of the decision to hold on to the view of ownership of learning as an aspect of student influence. It has not been possible to stay within the framework of constructivist learning to study student influence on the learning environment and I, therefore, provide an overview of my reasoning around this development.

4.1 Ontological and epistemological views underpinning this research

Within social and natural science there is an ongoing discussion of how data and observations are theory-dependent\(^7\), (Feyerabend, 1993; Kuhn, 1970; Popper, 1997; Weber, 1991). The theoretical foundations on which the observations in these studies will be based have, therefore, to be described and made visible. An observer takes decisions about what observations are relevant and how to conceive these data, as well as about how to communicate them to others. An ontological assumption is that natural phenomena exist independently from human theories about them, an assumption that is line with contemporary physics theory as the science of the material world. Learning theories carry with them assumptions about the learner and his/her relations to the environment of objects events and other persons.

There are more then fifty learning theories\(^8\) which might determine different units of analysis appropriate for the theory of learning in use and for the phenomenon under investigation. Learning theories imply the following: 1) a view of the student in society, 2) a view of what is important to learn and 3), a view of how successful teaching is maintained. How we look upon learning is dependent on the society and educational system within which we live. Our view of learning changes when society changes because of economical, sociological, political, and psychological issues. The constructivist perspectives of learning

\(^7\) “In particular, our most recent examples show that paradigms provide scientists not only with a map but also with some of the directions essential for map-making. In learning a paradigm the scientist acquires theory, methods, and standards together, usually in an inextricable mixture. Therefore, when paradigms change, there are usually significant shifts in the criteria determining the legitimacy both of problems and of proposed solutions”. (Kuhn, 1970, p. 109)

\(^8\) Data from TIP : The Explorations in Learning & Instruction: The Theory Into Practice Database 
http://tip.psychology.org/theories.html
had a major theme that learning is an active process in which the individual learner constructs new ideas or concepts based upon their current/past knowledge. The situated cognition theories and the situated learning theories developed in the 1990s (Lave, 1988; Lave & Wenger, 1991) argued that learning as it normally occurs is a function of the activity, context and culture in which it occurs; i.e., it is situated. This was, thus, in contrast with most classroom learning activities which involved knowledge which was abstract and out of context. Social interaction is the critical component of situated learning - learners become involved in a "community of practice" which embodies certain beliefs and behaviors to be acquired. Compared to the Vygotskian idea about the zone of proximal development, the process of Lave’s "legitimate peripheral participation" situated learning is usually unintentional and vocational, rather than deliberate. Brown, Collins and Duguid (1989) emphasised the idea of cognitive apprenticeship:

*Cognitive apprenticeship supports learning in a domain by enabling students to acquire, develop and use cognitive tools in authentic domain activity. Learning, both outside and inside school, advances through collaborative social interaction and the social construction of knowledge.*

*(Brown, Collins, & Duguid, 1989)*

The political and social consequences are difficult to manage if authentic environment for science learning is physics research or technological production or something else. The question is then if education is mainly for society or mainly for the individual intellectual and vocational development. In this respect, a contemporary theorist within sociology, Alain Touraine (2002), proclaims a school where the individual constitutes her/himself as more important than a school for the socialisation of norms (Touraine, 2002, p.380).

Situated cognition adds a perspective of vocational education into theoretical education that is of great interest for students who always search for “why” and “how” and not only “what”, i.e. a need to understand the content of education in its meaningful context. I find this of value to develop both as teacher designed tasks and as student generated questions.

### 4.1.1 The view of learning as meaning making

Bruner (1990) argues for understanding mind as a creator of meanings. He finds that only by breaking out of the limitations imposed by a computational model of mind can we grasp the special interaction through which mind both constitute and are constituted by culture (Bruner, 1990). Contemporary psychological and language researchers have become
increasingly concerned with understanding of how learning is influenced by social experience amongst peers under guidance from their teachers (Barnes, 1976; Wertsch, 1991). Also science education researchers have become aware of the importance of classroom discussions (Enghag & Niedderer, 2005; Mortimer & Scott, 2003; Webb & Treagust, 2006). How the social experience of language is seen as a major shaper of cognition is described by (Barnes & Todd, 1995; Edwards, 2005; Mercer, 2000, p.136). The view of learning as being dependent on the social environment and of talking to others became obvious with the opportunity to tape-record and video-record classroom interactions. Contemporary learning theories differ more about the unit of analyses than about learning as influenced, or not, by the social context.

Piaget (1896-1980)\(^9\) first emphasised the processes of conceptual change as interactions between existing cognitive structures and new experience. The constructivist view, based on the theories of Piaget, say that we construct our cognitive abilities through self-motivated action in the world. In this theory, the emphasis is placed on the student rather than the teacher. Teachers are seen as facilitators or coaches who assist students to construct their own conceptualisations and solutions to problems. Bruner (1986) called this 'scaffolding' learning. Bruner views learning as an active process in which learners construct new ideas or concepts based upon their current/past knowledge. The learner selects and transforms information, constructs hypotheses, and makes decisions, relying on a cognitive structure to do so. Cognitive structure provides meaning and organisation to experiences and allows the individual to "go beyond the information given" (Kearsley, 2006).

With the concept “Zone of Proximal Development”, Vygotsky (1978) put forward that children learn from “more competent others”. When we work together with others their support enables us to produce results we could not have done on our own. The use of language is an important element in this.

\[\begin{align*}
\text{The distance between the actual developmental level as determined by independent} \\
\text{problem solving and the level of potential development as determined through problem} \\
\text{solving under adult guidance, or in collaboration with more capable peers} \\
\text{(Vygotsky, 1978, p.86).}
\end{align*}\]

\(^9\) Data from TIP : The Explorations in Learning & Instruction: The Theory Into Practice Database http://tip.psychology.org/theories.html
The view that learning is not transferred from person to person but rather a process of comparing and checking own understandings with ideas that are being rehearsed on the social plane is emphasised by Mortimer and Scott (2003), whose communicative approach is based on the theories of Vygotsky regarding internalisation and from Bakhtin regarding the dialogic nature of understanding. They regard meaning making as a dialogical process which always entails bringing together, and working on, ideas (ibid, p.11). Within their socio-cultural perspective learning, a process of internalisation is seen which involves a movement from the social to the individual (ibid, p.10). Mortimer and Scott acknowledge the constructivist paradigm for the substantial body of research of students’ alternative conceptions. However, they find the research of how meanings are developed through language belonging to a post-constructivist paradigm, as moving on, but not ignoring, that constructivist programme (ibid, p. 4). Other developments of Vygotsky's ideas suggest that we learn from others, not necessarily because they are more competent, but because they think differently.

Mercer (2000) refers to 'interthinking' occurring when people talk and develop ideas together and he proposes an “Intermental Development Zone” which we can imagine to be the area between us when we talk together and combine our ideas. This shifts the framework from self-identity towards an assumption of intersubjectivity (Edwards, 2005). Often we can clarify our ideas and thinking by expressing them verbally. Mercer analysed discussions taking place in learning contexts and has identified evidence of changes in thinking and ideas. He takes the term 'exploratory talk', from Barnes (1977) for dialogue “in which differences are treated explicitly, as matters for mutual exploration, reasoned evaluation and resolution” (Mercer, p. 173).

The view of learning proposed by Barnes and Todd (1995, p. 11) is that learning focuses on the learner’s reinterpretation of experiences that the learner has already had. Through talk the learner can reconsider the experience and also reshape the ideas that are, until now, held in a vague and ill-defined way. The teachers’ task would be to organise situations that encourage students to work on their own understanding.

I agree with Barnes view of learning as reinterpretation of experiences that the learner has already had. My interest is the individual student’s learning but the unit of analyses is still the group discussion because it provides the only possibility that there is of detecting how understanding and meaning making is developed. I find it possible to follow a single student’s change in view of a phenomenon in his/her dialogic with peers in small-group work.
4.2 Exploratory talks

Douglas Barnes entitled peer discussions for meaning making as “exploratory talk” (1973). In Barnes’ description of children’s classroom talk, he distinguishes “exploratory talks” from its counterpart, “the final draft”. Exploratory talk is used when students work on developing understanding. It is often hesitant and incomplete, and the students use half-sentences. This kind of talk enables the speakers to try out new ideas and is focused on the speaker clarifying their understandings. To be able to enter exploratory talks the environment has to be secure and the students need to feel trust and acceptance. Small-groups are an ideal environment for this talk to develop. Barnes described how students found exploratory talk highly useful for problem solving. He 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 acceptable to brainstorm in order to try to reach understanding.

According to Barnes, the contrary way of talking was the final draft talk that was focused on audience needs and expectations and was used when a presentation had to be given in front of an authoritarian or unfamiliar audience. The final draft talk was a description of the result of the thinking presented in as orderly a 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 & Todd, 1977).

I see a challenge nowadays for education to give students time for reflective thinking and the opportunity to use exploratory talk in order to reach understanding. Exploratory talks are a sign of the students’ motivation to get involved in a learning process. When Barnes describes exploratory talks in Language in the Classroom (Barnes, 1973), he sees 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. (Barnes, 1973)

Barnes and Todd (1977, p. 19) analysed their audio-taped and transcribed small-group talks a in a descriptive system of the social and cognitive functions in exploratory talks in two levels with four functional components (based on Halliday’s three components [Halliday, 1970]). They retained the distinction between social or interactive speech events and cognitive aspects of speech events. The interaction was divided into two levels; discourse moves and social skills and cognition into the two levels logical processes and cognitive strategies.

In discourse moves the sequential relationships in the conversation is made clear. In the logical process a relationship between a question and an answer is established. By showing which member in the group who contributed each utterance it would be possible to represent schematically the pattern of thought-development in a discussion, says Barnes and Todd (p.21). By the two levels of the cognition category they wanted to describe learning on a larger scale, and focusing on the ability to control the group’s progress through the task, the management of competition and conflict and the giving of mutual support. By cognitive strategies the attention is turned towards the students application of knowledge to the tasks put before them.

| Social and cognitive functions in exploratory talks (Barnes & Todd 1977, p. 20) |
|----------------------------------|----------------------------------|
| **Level 1**                      | **Level 2**                      |
| 1.1 Discourse Moves             | 2.1 Social Skills               |
|   ▪ Initiating                   |   ▪ Progress through task: Clarifying given questions, |
|   ▪ Extending Qualifying,       |   ▪ Shifting topic, ENDing a discussion, Managing |
|   ▪ Contradicting               |   ▪ manipulative tasks          |
|   ▪ Eliciting Continue, Expand, |   ▪ Competition and conflict: Competition for the floor, |
|   ▪ Bring in, Support, Request  |   ▪ Contradiction, Joking, Compelling participation |
|   ▪ information                 |   ▪ Supportive behavior: Explicit agreement, Naming, |
|   ▪ Responding Accepting        |   ▪ Reference back, Explicit approval of others, |
|                                 |   ▪ Expression of shared feeling |
1.2 Logical Process
- Proposes a cause
- Proposes a result
- Expands loosely
- Applies a principle to a case
- Categories
- States conditions under which a statement is valid or invalid
- Advances evidence
- Negates
- Evaluates
- Puts alternative view
- Suggests a method
- Restates in different terms

2.2 Cognitive Strategies
- Constructing the question: Closed task, open task
- Raising new questions
- Setting up hypotheses: Beyond the given, Explicit hypotheses
- Using evidence: Anecdote, hypothetical cases, using everyday language, challenging generalities
- Expresses feelings and recreating experience: Expressing ethical judgments, Shared recreation of literary experience

2.3 Reflexivity
- Monitoring own speech and thought: Own contributions provisional
- Interrelating alternative viewpoints: Validity of others
- More than one possibility, Finding overarching principles
- Evaluating own and others’ performance
- Awareness of strategies: Audience for recording, summarising, moving to new topic

Table 3: Social and cognitive functions in exploratory talks (Barnes & Todd 1977, p. 20)

Webb and Treagust (2006) have found a clear and statistically significant improvement in the mean test scores on problem-solving and reasoning of pupils in Grade 7 science classrooms who participated in the classroom discussion initiative (exploratory talks) over those of the comparison groups. In their study, trained teachers used specially developed “hands-on” activities, shared reading of text, and used “question and challenge” posters to initiate and sustain discussion of an exploratory nature in their science classrooms.

Edwards, (2005) examined the occurrence of “exploratory talks” amongst peers in collaborative groups in secondary school mathematics classrooms. The findings support a view of social dialogic amongst peers as a means of generating talk that culminates in cognitive change. They found that the length of time a group had experienced a socio-cultural and emancipatory learning environment had a direct relationship to the amount of exploratory talk evident. Another finding was that groups with peer tutoring relationships, in which one student gave answers without explanations limited the opportunities for exploratory talks. Being able to trust others facilitates being able to take risks involved in learning new concepts. They found in their study how cognitive growth can happen within groups without the presence of a “more learned other”, as Vygotsky suggested within the zone of proximal development.
4.3 Ownership of learning

The theory of student ownership of learning does not explicitly define a specific theory of learning. Instead it stresses the circumstances that are of importance for successful learning to happen at all. The question of student influence has its roots in the frameworks of constructivism and accentuates how the individual intellectual development is of importance, and is, in fact, the goal for all education. (There are other focuses challenging this learner-centred view; one is the view that puts the level of content itself as the basis of education and another is the view that communication itself is the goal of education.) My own view of learning builds on the assumption that learning is individual but develops in the cognitive conflicts that individuals experience when they expose their ideas in “exploratory talk” (Barnes, 1977; Mercer, 2000) with other persons. This means that learning takes place also among peers, and not only dependent on the influence of authoritarians. This does not mean that teachers are unnecessary. On the contrary they are very important but their role is to organise instructional settings so opportunity for learning is possible at all, and to give information and explanations when needed. The balance of information, feedback and the organisation of challenging task is the teachers’ responsibility. A combination of traditional teaching and parts of the course with cooperative learning groups is one way to search for an optimal situation.

SOL provides a theoretical framework that makes it possible to analyse the classroom work from the perspective of students’ influence. The pedagogical challenge that comes with the concept of SOL is to change the authoritarian physics education, with a fixed content to be transferred from teacher to students by lectures and laboratory work, towards a learning environment that is more inviting and tempting to student contribution and student/teacher and student/student communication. Balancing the relationships of power and authority, creating spaces for everyone to contribute, and advocating that students be resources for one other is what ownership is about (Rainer & Matthews, 2002).

*Student ownership of learning* is an important challenge for physics education, as it focuses on the students’ opportunity to influence both the organisation of activities, the content in the activities, and the individual learning. “As a political concept, ownership describes the power relationships between teachers and students. As an epistemological notion, ownership describes the complex ways in which individuals make sense of their experiences and of the world around them” (Dudley-Marling & Searle, 1995, p.viii)
Studies using ownership as a theoretical framework can be found in research in different areas such as language learning (Dudley-Marling & Searle, 1995), teacher education (Rainer & Matthews, 2002), science education in urban settings (O’Neill & Barton, 2005) and in instructional systems technology (Savery, 1996; Savery & Duffy, 1995). It is only more recently that this concept has been applied to science education research; in physics education at university level (Milner-Bolotin, 2001; Enghag, 2004). Thus, ownership theory has grown from teaching in informal settings into formal settings and from language teaching into science teaching.

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 (Deci, Vallerand, & Ryan, 1991, p.325). Motivation, performance and development will be maximised within social contexts that provide people with the opportunity to satisfy their basic psychological needs for competence, relatedness, and autonomy (Ryan & Deci, 2000, p.57). Relatedness to others as to teachers and peers is important especially when the student is more extrinsically then intrinsically motivated.

When we study student ownership of learning, a border crossing from the socio cultural situation in the classroom to the individual knowledge construction and meaning making of the student take place.

When humans are mentally active, they are agents in their own learning. They own that knowledge, and they relate it to their own experience. Hence ownership could be described as the linchpin or a central and cohesive element of knowledge construction. (Rainer & Matthews, 2002, p.22)

Milner-Bolotin (2001) developed her concept “learner ownership” in an individual direction by introducing a questionnaire in which the students were asked directly about their feelings of ownership, responsibility, and feelings of being in control. Her study focused on student autonomy in choosing a project topic, their motivational orientation, student ownership of the project and their interest in their 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 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 of 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 in the following way:

A learner has a high degree of ownership of the project if the learner

- 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
- feels in control of the learning process he or she is involved in via making decisions, and being a proactive, rather than reactive learner
- takes responsibility for the learning process as well as the result of the project.”

Figure 3: 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 defined ownership in physics education, in a problem-based learning environment with small group-work, as the intersection between taking responsibility, finding a personal value and feeling in control and measured the individual status of ownership with a questionnaire.

Savery (1996) presented “the model for ownership of learning”, that draws clusters of psychological principles from the psychologist McCombs (McCombs, 1993). In the following four categories, he defines behaviour indicators to study: 1) metacognitive and cognitive factors, 2) affective factors 3) personal and social factors and 4) individual differences. 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 is not explicitly defined, his behaviour checkpoints form a picture of how he understands the ownership of learning. He describes metacognitive and cognitive factors as: “Sets meaningful goals”, “Self-monitoring”, “Self-directed”, and “Construct knowledge”. Within this study (Saver, 1996) 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.*

Whereas Milner-Bolotin endeavours to relate learner ownership to motivational aspects, Savery has, instead, a fostering attitude towards implementing a learning environment that gives ownership to students. My own attitude in this thesis is, rather, to make a more fine-grained analysis of what ownership of learning represents and, in particular, to highlight differences between the group level and the individual level which are not discussed in these earlier studies.

### 4.4 Mimesis as a metaphor to individual ownership of learning

When we *learn*, the learning process has duration in time that is not easily described. In the small-group work talk that I have video-recorded, I follow the communication that arises between students who carry out a task. I have chosen to categorise this action in time from a mimesis perspective where I consider it possible to describe the beginning of the learning process mimesis by prefiguration, configuration, and refiguration. Ricoeur named these stages of new awareness of a phenomenon in his development of Aristotle’s’ Poetics (Ricoeur, 1984; Ricoeur, 1992).

The student often begins the conversation by telling about an own experience or an own question that has become of current interest due to the task the teacher has given them. This prefiguration is expressed and can be seen in the transcript of the conversation. When the question later recurs, or comes back modified, it is my estimation that a configuration has happened. Sometimes this is followed by a third stage, a refiguration, where the original question has been answered, or at least some new insights into the question are shown.

The conversation in the groups covers many complex courses of events and can develop in many directions. When students communicate with the purpose of understanding something, there is a constructive conflict and an honest intention with regard to a joint construction of understanding the phenomenon at hand.
By using a category system for individual ownership of learning, the concept of mimesis and its historical development has been my particular interest. Mimesis refers to fundamental expressions of our human experience within the world - as means of learning about nature that, through the perceptual experience, allow us to get closer to the “real”. During the course of history, mimesis has been connected to different human activities such as imitating, copying or reproducing. In most cases, mimesis is defined as having two primary meanings - that of imitation (more specifically, the imitation of nature as object, phenomena, or process) and that of artistic representation.¹⁰

Plato’s Socrates expressed a critical view of any type of imitation in art and poetry (Platon & Stolpe, 2003, p. 414). For him, art and poetry imitate in second and third hand because the material world already are imitated in our minds. Socrates wanted to show that only fools believe that knowledge could be produced by further imitation, such as when an artist paints a picture of a shoemaker who repairs a shoe.

Melberg (1992, p. 38) points out how paradoxical Plato is in his position regarding mimesis; on one hand rejecting the idea, on the other hand himself being the big mimic by his dialogues in print and his narrative stories. However, I find, when Plato in the Republic, for example, lets Socrates and Glaucon talk about how narratives and art influence the minds of young people, it is not the copy or imitation itself, but more the possibilities there are to tell lies and to destroy young minds; the same worries that people have nowadays about how movies and aggressive computer-games will have an adverse influence on children. (See Staten Bok 3 401 cd). As far as I see it, Plato’s view (with the voice of Socrates) is a kind of claim of power that is easily recognised within different groups wanting to consolidate their position, whether it be political, religious, or perhaps even scientific. Such groups find it important that individuals are cultivated into “the right thinking” and that they do not end up in situation where they question and develop the conventional ideas. This constraint leads many students to be abandoned and to make mistakes. Instead, it would be more desirable that the high-quality talk could help students to come through what Plato is afraid of, the bad and the poor, and that the good talk could help both the wise and the young to develop their thinking. This, for me, is what makes the concept of mimesis so exciting. I consider mimesis to be the good talk where people can get new insights about reality and, by that, grow.

In the Republic, Plato gives an idea of the world that is almost static, without the space of time. Mimesis is to Plato imitation, but never change. The ideal republic seems to be the one

¹⁰ See The University of Chicago: Theories of Media: Keywords Glossary: mimesis Available at http://www.chicagoschoolmediatheory.net/glossary2004/mimesis.htm
that never changes, ruled by the philosophers; a peaceful static entity. Aristotle takes quite a
different view, which might be due to his empirical studies of animals and plants.

*Aristoteles’ mimesis is defined by mythos and praxis, which orients the concept towards
time and action – to compare with Platons’ mimesis that comes close to image and copy.
(Melberg, 1992, p. 47, my translation from Swedish)

Both Plato and Aristotle try to describe the relation between art and reality. With Aristotle
will the concept of mimesis include a link between the state of mind a person is within and
another state; it refers to a change because of new perception or insight. Within Mimesis the
duration of learning is implied. It includes and allows personal growth. To learn is to make
new experiences and to relate the new experiences to the old ones to get meaning and
understanding.

To be able to explain course of events gives implications in somebody’s self-
understanding (Lemke, 2000). When you can discuss real world event in physics terms, you
have changed to another, you have become a scientist yourself. They way to mimesis go
through communication with others.

4.4.1 Experience related to Mimesis

Mimesis starts with a personal experience that needs to be “cultivated” for progress in
understanding and new insights. The concept experience itself is associated with empirical.
By using the concept of experience, an involvement in the never-ending discussion about
empiricism/rationalism seems unavoidable. The western traditions of thinking have come to
include this dualism and focus on the importance of the consciousness in comprehension of
the world; an epistemological realism and an ontological dualism.

Descartes “followed the analysis backwards to the primitive experience elements that
were available in principle for all thinking people in all cultures” (Toulmin, 1995, p. 33).
Toulmin, however, presents a view of Descartes that is greatly influenced by the context in
which he lived.

Toulmin maintains that it was in polemic with a well-known thinker, Montaigne, from the
16th century that Descartes directed his cogito ergo sum (I think, therefore I am). Toulmin
argues for the opinion that other personal experiences, such as the murder of Henry IV of
France, and Descartes experiences of the religion wars, were the background for Descartes’
rationalsm being so successful; the need in society of law and order was the ground for the
growing rationality. Consequently, Descartes got the impetus to drive his own questions by his experiences. The difference between Montaigne and Descartes’ views of experiences is, according to Toulmin, that for Montaigne life-experience was “the practical experience that every person accumulates in interplay with many peers” but for Descartes “the experience of thought was the raw material that helped the individual to mentally make a map over the tangible world.”

Experience differs from knowledge; knowledge is a general categorisation; experience is personal and individual and has a direction. Dewey, (1997, p. 38) states how “every experience is a moving force. Its value can be judged only on the ground of what it moves towards and into.” Dewey stresses the active side of experience in two ways; one is how experiences influence the formation of attitudes of desire and purpose, and the other is how it changes, to some degree, the objective conditions under which experiences are held. He calls these two principles continuity and interaction. What is learned in one situation becomes an instrument of understanding and dealing effectively with the situations that follow (ibid, p. 44). To obtain an opportunity to learn from own experience is important for the personal growth. There is always a risk within education that individuals lose the desire to apply what they have learned and lose the ability to extract meaning from their futures experience when they occur. Dewey considers the consequences of an education based upon experiences to be a social process; the teacher loses the position of external boss, but takes on that of a leader of group activities.

The educator is responsible for a knowledge of individuals and for a knowledge of subject matter that will enable activities to be selected which lend themselves to social organisation in which all individuals have an opportunity to contribute something, and in which the activities all participate in are the chief carrier of control (Dewey, 1997, p. 59).

Experience is a concept that follows humankind through history and is controversial today because of its origin within individuals. Jay (2005) in his four hundred pages, Songs of Experiences, discusses the development of the autonomous discourses about cognitive, religious, and aesthetic experiences, and finds it impossible to reduce it to a general category. However, the links between experience and everyday life, and experience and the “lived body” as the holistic site of experience seem to remain in the most all-inclusive sense of the word (p. 402). Experience is made possible by the tension between subject and object, and it is hard to deny the necessity of an outside to the interiority of the subject, but experience is

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11 Ibid, s.70
also described as sometimes “gravitating towards its subjective pole and sometimes to its objective” (Jay, p. 405). Jay puts forward the example of being employed in either a subjective or an objective genitive case. This can be understood as an epistemological subjective experience and also as the experience of real objects in the world. Jay propose an interplay between subjectivity and intersubjectivity; “bodily sensations and the assent of all who share the same capacity for appreciating beauty, it forces us to acknowledge that experience is at once deeply personal and yet to a significant extent capable of being shared with others.” (ibid, p. 406)

Experience, however, involves an encounter with otherness, which leaves the subject or subjects no longer where they were before it occurred, in produces a fortress of sameness, which it then protects against further experimentation. (ibid, p. 408).

4.5 Paradigms of learning

Ownership of learning theory is concerned by two currents or streams in contemporary physics education; one is the interactive learning paradigm versus the curriculum paradigm, and the other is within the curriculum paradigm to respond to the physics as a “discipline – culture”. The view of communication as “a fight in love” is very close to exploratory talks during group work.

4.5.1 The interactive learning paradigm versus the curriculum paradigm

Lemke writes about two paradigms of learning and education contending in our society today, and how the new technologies will significantly shift the balance between (Lemke, 1994). He describes the curricular learning paradigm that dominates institutions such as schools and universities as an educational paradigm developed in the area of industrial capitalism and factory-based mass-production and in close philosophical agreement. The curricular paradigm assumes that someone else will decide what you need to know, and will arrange for you to learn it all in a fixed order and on a fixed schedule. Lemke argues how this paradigm is widely refused and resisted by students, and how its end results provide no more usefulness in the non-academic world than “a few text literacies and certification as a member of the middle class.”
Lemke refers to the other learning paradigm as the interactive learning paradigm and this dominates such institutions as libraries and research centres. “It assumes that people determine what they need to know based on their participation in activities where such needs arise, and in consultation with knowledgeable specialists; that they learn in the order that suits them, at a comfortable pace, and just in time to make use of what they learn. This is the learning paradigm of the people who created the internet and cyberspace. It is the paradigm of access to information, rather than imposition of learning. It is the paradigm of how people with power and resources choose to learn”.

Lemke finds that these two educational paradigms are in fundamental conflict. He guesses that “many disappointments that schools are not more eager to adopt computer-mediated information technologies may perhaps be laid at the door of this largely unrecognised conflict”.

I do not agree with this total polarisation. These tendencies are too dominated by the industrial world view once again; the knowledge management of today. I work for a middle-way; increased ownership but still with guidance into a scientific world by teacher proposed tasks that are challenging, yet also suggesting a feasible way. It is my opinion that it is time to make a canon or catalogue of the big issues to be solved within science today and challenge young people with that list of problem-solving issues. Young people cannot see the problems, but have a great capacity of problem-solving when they are faced with the questions. Such a list could make them aware of these issues, and that is a kind of experience. Time to think over a longer time, even if it is not particularly active, provides the opportunity for problem-solving when it is needed.

4.5.2 Learning by communication as a “fight in love”.

There is a long unsolved discussion from the past where rationalism takes the view that deduction by reason alone is the basis of all knowledge and contrasted with empiricism, which argues that all knowledge must ultimately be derived from the senses. This ongoing debate would appear to have a new input by Ricoeur. Descartes takes for granted a *Cogito* able to create knowledge independent of the outer world, and see this act of thinking as the guarantee for absolute knowledge. Nietzsche’s statement of God’s dead was a critic of the subject as the ground of knowledge, (Ricoeur, 1992, p.11). In the fight between objectivists

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12 Journals covering the knowledge management: http://www.kmworld.com/Archives/
13 http://www.iep.utm.edu/r/ricoeur.htm#H5 The Internet encyclopedia of philosophy: Paul Ricoeur (1913-2005)
and relativists will the position of Ricoeur be in between: He gives the image of the vulnerable subject, *Cogito blessé* (Kristensson Uggl, 1994). Ricoeur does not give up the idea of a conscious subject, but stresses that the subject has contact with itself in a complicated way, i.e. it finds itself in communication with others.

*In critical relation to Descartes subject, who does not need to communicate, and to Nietzsches subject who can not communicate, Ricouer put forward a subject who must take a long and dangerous way round to find itself by interchange with others. (ibid, p. 56, my translation from Swedish)*

The communication often takes the character of a fight in love. Only the struggle can guarantee the ambition to find the truth, and only love can guarantee that communication stays alive and not transform into a war (ibid, p.91). This view of communication is very close to exploratory talks during group work.

4.5.3 Physics as a discipline - culture

A teacher proclaiming a certain structure for physics knowledge usually addresses something specific (Tseitlin & Galili, 2005, p. 17). Tseitlin and Galili (2005) advocate physics as the dialogue among discipline-cultures rather than as a cluster of disciplines to be an appropriate subject of science education. They describe the discipline-culture to contain elements of knowledge belonging either to 1) central principles and paradigms (nucleus), 2) normal discipline area (body of knowledge), and 3) rival knowledge of the subject (periphery). Physics is taught too often as an engineering discipline, and mathematical formalism is used to train the application of the theory to problems. Tseitlin and Galili find that physics is often presented to students within the normal discipline area (body of knowledge). Students (philosophers) more interested in principles and ideas about the subject gravitate to the nucleus of physics. Students who are inclined to criticise the presented knowledge gravitate to the peripheral knowledge of discipline–cultures. This view of physics opens up for a philosophical implementation of physics in school; – an approach that is perhaps more inviting for females.
5 Study objectives and design

5.1 Objectives

The ultimate goal of this study is to develop the concept ownership of learning in such a way, both theoretically and empirically, that it will be possible to ascertain whether students can be said to have ownership of their learning during small-group work with miniprojects and context rich problems. The output of the study is to find the relevant aspects of importance for enhancing the learning environment in physics classroom. Thus, the general question is:

How does ownership of learning contribute to improve teaching and learning in physics?

Before this broad question can be answered, it is necessary to develop categories for student ownership of learning that allow us to answer the question: How is student ownership of learning seen in the classroom?

The major objectives of this study are, therefore, as follows:

Objective 1: Develop theoretically the concept student ownership of learning (SOL) and develop empirically the categories that allow us to see SOL in concrete learning and teaching situations.

- Describe and clarify group and individual ownership of learning during small group work in physics.
- Use a system of categories to distinguish different forms of ownership and discuss how the categories work.

Objective 2: How does the conversation develop during work individually and as discourse?

- Describe the discourse – especially in the direction of exploratory talks - and elucidate the discourse with flow charts.
- How do students own questions, everyday life experiences, and own ideas or questions influence small group work talk during problem solving in collaborative groups in physics?

Objective 3: How is ownership and communication related?

- Describe the conditions for exploratory talks to develop.
- How are exploratory talks related to ownership of learning?
The approach to meeting the three objectives outlined above was driven by an interaction between theoretical studies of related literature and empirical studies of small-group work in physics classrooms.

5.2 Research Design

The research design employed a qualitative, case-study approach to collecting data about ownership of learning found in two different instructional settings: 1) the miniproject (MP) and 2) the context rich problem (CRP), conducted into three different physics courses. In addition, during the course of the study, I also collected theoretical literature from nearby theoretical fields, searching for a balance between plausible theoretical assumptions and emerging theory from the data at hand; a fruitful strategy within subject didactics.

Finding a balance between plausible but intuitive and valid but restricted models is another challenge of research in the field of subject didactics (Fischer, 2005, p. VIII).

Qualitative research is appropriate to document in detail the conduct of everyday events and to identify the meanings that those events have for those who participate in them and for those who witness them (Erickson, 1998, p. 1155). Case studies typically use multiple methods and are valuable where broad, complex questions have to be addressed in complex circumstances.

Case studies using qualitative methods are most valuable when the question being posed requires an investigation of a real life intervention in detail, where the focus is on how and why the intervention succeeds or fails, where the general context will influence the outcome, and where researchers asking the questions will have no control over events. As a result, the number of relevant variables will be far greater than can be controlled, so that experimental approaches are simply not appropriate. The case studies reported in this thesis are carried out from data collection that includes several data-sources. Erickson (p.1159) states how research is “re-searching, to seek and seek again, recursively”. The recursive process of observations of the data and of generating theory is based on results of previous research, discussions of the improvement of science teaching, own experiences, ideas and expectations. (See Paper I, II)

From flow charts of the video/audio-taped conversation and from transcripts of group talk during work with miniproject and solving context rich problems, hypotheses about ownership of learning have emerged. Categories have been constructed and reconstructed in a process of
looking at the data to find positive and negative cases of ownership. New indicators have emerged after going through the data again. To minimise bias in the analyses, interrater reliability calculations has been made both for establishing the categories and gathering indicators, and for the final analyses (See papers III, IV, V). During the whole process the evaluations and findings have been reflectively discussed between the members of the science education research team at Mälardalen University and also in the project “Context and conversation in physics education”, a project supported by the Swedish Research Council and conducted in cooperation between Umeå University and Mälardalen University. Figure 4 illustrates this interpretative analysis of the data and theory generating process.(Niedderer, 2001a).

- Results of previous research
- Discussion of the improvement of science teaching
- Own experiences, ideas and expectations
- Analyses of Small-group work talk

DATA

Transcripts from group talk during work with mini-project and solving context rich problems
Flow charts of the conversation

Theory generating: Categories for ownership of learning

1 Process of looking at the data to find evidence and counterevidence
2 New categories emerging after going through the data again.

Figure 4: Method for interpretive and theory generating analysis (from Niedderer, 2001a)
5.3 Data collection

The research is grounded in data collection from audio/video-filmed small-group sessions where students are solving context rich problems with group discussions and/or working with miniprojects in three different educational contexts. Questionnaires, tests, and interviews are used as complementary data.

The first data collection was executed in order to investigate how motivation, ownership and competence are related when students study physics in small-group work with miniprojects. The study was conducted with fourteen student teachers in physics who were studying their second physics course, electrodynamics, when they worked for two weeks in small-groups with miniprojects in physics during 8 weeks of autumn 2002. I was the teacher for the course.

The miniproject is an instructional approach. Students work for a limited amount of time on their own questions, with their own methods, and by reaching 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 that they themselves choose and have a deep impact on. They can make use of their earlier experiences, and can still cooperate with peers in solving problems. They can try to grasp totally new topics or go deeper into something well known. Used as a complement to ordinary teaching, the miniproject is a way of giving teachers the opportunity to invite enhanced student contribution in the lessons. This study is reported in my licentiate thesis (Enghag, 2004). The purpose of the study was to determine the following:

- What type of miniprojects do student teachers prefer to work with?
- What categories belong to motivation, learner ownership, and competence?
- A description of the small-group work as a process.
- A comparison the different MP groups to see differences and similarities.
- Connections between motivation, learner ownership and competence.

Findings from this study were as follows:
The fourteen student teachers needed to improve their common knowledge in physics and found technical applications or nature phenomena preferable as miniprojects. They also became motivated and found the projects fun and interesting. The process for each MP Group
was multifaceted. The communications between the members were crucial. If exploratory talks and own questions occurred the learner ownership was connected to high intrinsic motivation and increased competence.

Despite the same instructional setting, the different small-groups developed their miniproject quite differently. The students appreciated the level of freedom to carry out the project. Two groups came up with questions of their own and demonstrated their ability to go into exploratory talks. They showed high value of ownership and intrinsic motivation. The result of this study showed a need for further refinement in defining the concept of learner ownership. Both ability and possibility of ownership seemed to be crucial. Management and responsibility for the learning process, together with the communication situation inside the group, support learner ownership if group members are able to participate in exploratory talks, if they put forward their own questions, and if they have different strengths and weaknesses so that no informal leadership occurs. The highest level of ownership as a part of control, responsibility, and personal value was found to have two strong indicators: exploratory talks and the presence of emerging own questions.

The second data collection was executed with 15 pupils in a science programme in upper secondary school who worked in small-groups, partly with miniprojects, and partly with context rich problems, during 4 weeks of their ordinary schedule during spring 2003. My licentiate thesis reported from multiple case-studies based on the first two data collections related to motivation, ownership and competence. (See Enghag, 2004). Peter Gustafsson and I video-filmed the CRP-sessions and I carried out all of the other data collection myself.

The third data collection was made at university level during 8 weeks in autumn 2003 and during 8 weeks during autumn 2004. The students in the Aeronautical Engineering Programme solved context rich problems in 20% of the course time. Peter Gustafsson and Gunnar Jonsson carried out the data collection in 2003. A questionnaire in which the students evaluated problem-solving with CRPs compared to text-books problem was executed by Gunnar Jonsson, and interviews of four students by Peter Gustafsson. Time-lines of the problem-solving was made by all three of us. Gunnar Jonsson and I carried out the data collections in 2004. We then gave the students the opportunity to choose between several CRPs that we had constructed ourselves and I also carried out 13 interviews with students in the course. Gunnar Jonsson was the teacher of the course.
5.4 Methods of data collecting
Audio/Video-recordings, transcripts, and flow charts

Audio-recording
In the first data collection, student teachers worked in small-groups with miniprojects that they had chosen from a list proposed by the teacher. They were instructed, and had agreed, to audio-tape themselves during this two weeks activity. A first audio-recording was done before the individual choice of miniprojects was made, when the 14 students were divided into three groups. The second audio-recording was made by the students themselves, when they constituted five groups with 2-4 members. They recorded their work with cassette recorders when they worked at the laboratory or the library. These two audio-recordings were transcribed in part for four of the five groups. Some transcripts are given in Appendix 1. In the second and third data collection the group talks were audio-taped by digital audio recorder as a complement to video-recording made by the researchers.

Video-recording
The researchers video-filmed all miniproject group presentations (5 + 5) and made full transcripts from these. The researchers also video-filmed the work with context-rich problems; during autumn 2003 four groups were filmed (using old cameras with VHS tapes), but because of the low audio quality, only one full transcript of one group was made. However, we filmed (with DV camera and small tapes) 12 groups during autumn 2004. In this instance, we also used digital audio-recorder as a complement to video-recording made by the researchers. The recorded groups were placed in separate rooms to enhance the quality of the sound.

Flow charts
The group-talk during the context rich problem-solving was at first summarised as time-lines by each of the three researchers. To analyse the discourse moves, they were visualised by flow charts. See Paper III, or V. The software used for this was Cmap tools available for download at http://cmap.ihmc.us

Interviews
14 students from the Aeronautical Engineering programme were interviewed after the third data collection. These interviews are, as of now, still not fully transcribed, but will be used in a later study.

Questionnaires
The first data collection included the (Milner-Bolotin, 2001) Ownership Measurement Questionnaire OMQ. The result is based on the students’ answers of how they have
experienced their learner ownership as an interactional effect between three components of
the 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 as: finding, feeling, and taking in the project work situation.

**Other methods**

CBAV Category based analyse of video tapes, (Niedderer et al., 2002) a technique we used
also for the audio taped lab sessions, was used. We categorised all individual talks every 30
seconds into 7 categories. (See Licentiate thesis Appendix 3 and paper I)

**Transcripts**

**Basic transcription symbols**

1 When someone continues after an interruption this is shown as:

   B: *That is as cold as in a fridge...*
   C: *...eight degrees I think.*

2 Gestures and other actions are explained within parentheses:

   C: *We have to do some little Q plus (points to the white-board)… I have a feeling here of...*
   D: *yeah...something*
   A: *Then we will get the smallest amount of ….smallest amount of ice that is needed for the temperature to rise and when it is all melted, it has become water.*
   D: *Yes, I am prepared to agree with that (nods towards B).*

3 Discourse moves are shown with different fonts:

   Three categories were observed whereby the participants: 1) invited conversation by
   asking or turning to the others with a request to say something (this step is under-lined in the
   quotations), 2) took over the conversation from each other by repeating an important word
   to keep the conversation going and to extend the issue (this step is bold in the quotations),
   and. 3) answered or qualified an earlier invitation or gave an opinion on something discussed
   earlier- (this step is given in italics in the quotations).

   An example:

   D: *I think so too, but “B”, what is an appropriate temperature?*
   B: *... an appropriate temperature is...*
   A: *zero degree*
   B: *no five degrees*
   A: *What do you think an appropriate temperature is?*
6 Results

In this chapter the progress towards the final definition of ownership as actions of choice and control is elucidated. The study took departure in instructional settings aimed for giving more space to the students to develop their own learning environment, but during this five years the complexity of what really goes on in small-group work have enriched the findings. The chapter 6.1 will show the progression in the theoretical description of ownership from paper I to paper VI.

6.1 Summary of papers

Paper I reports from the second data collection in upper secondary school. Paper I reports the students’ interest in physics based on questionnaires and student drawings. Their motivation to work with context rich problems and the time-line for the problem-solving were scrutinised by computer based analyses of video-films (CBAV), (Niedderer et al., 2002). The small-group conversation is analysed using the theoretical concept “exploratory talks” (Barnes, 1973) and my own concept “internal teaching”. The first definition of the concept ownership of learning as existing “in two levels”, group and individual, was used.

Paper II describes in detail how four girls working with a miniproject use exploratory talks and have ownership by choosing own questions to work with and reports from the second data collection in upper secondary school. Full transcripts from the small-group work and from the students’ presentation were analysed. The development of a conceptional conflict resulting in a conceptional change was found. Two girls show conceptual change of the concepts resistance and current during exploratory talks in miniproject preparation. Ownership is discussed in two levels: –group and individual.

Paper III took departure in the findings that own experiences and own anomalies of understanding were the driving force small-group work conversations. A categorisation of the conversation in physics-related and everyday life experienced was conducted, and an interrater agreement calculation confirmed the finding that the conversation started with a discussion based on everyday experiences that led the students into a physics talk. The case study use data from the third data collection. A first categorisation was also made of discourse moves and applied to the transcripts. One group of four students solved the context rich
problem “The Drink”. The individual student ownership of learning (SOL-i) was evaluated based on a categorisation from the Mimesis concept.

**Paper IV** is the main paper that develops the theoretical approach: student ownership of learning in two dimensions. SOL is distinguished into group ownership of learning (SOL-g) and individual student ownership of learning (SOL-i). Here this own theoretical framework is applied to two miniproject cases from the first data collection. Both case studies are evaluated with interrater agreement calculations, resulting in a clearer definition of categories. By clarifying that ownership of learning refer to actions of choice and control, a consistent model emerges. Group ownership refers to the groups’ realised opportunities, i.e. actions, to choice and control of the task itself. Individual ownership of learning refers to each student actions of choice and control; i.e. own questions/ideas as speech actions that come back. SOL-i is used as a single category, and the progression of ownership is followed by prefiguration, configuration and refiguration as indicators for this process. Mimesis accordingly becomes a metaphor to individual student actions of choice and control.

**Paper V** used the developed theoretical framework in cases from the third data collection. It reports case studies from when the CRP “The Key” (which I constructed myself) was the task. The students had increased group ownership by their realised opportunity to choose among different CRPs. The paper scrutinises three groups who chose to solve the same CRP. Individual student ownership of learning (SOL-i) was found in two of the groups, but only for one student in each of these groups. Exploratory talks were analysed in themes, and flow charts of the conversation were constructed. In this submitted paper the group ownership is called *conditional*, a fact we will change in the revised version.

**Paper VI** is a conference proceedings paper (in Swedish) discussing the categorisation of individual ownership of learning. A first suggestion to categorise is applied to the miniproject group “The Solar Wind” group, and students own experiences, as a starting point for their physics thinking, was described.

### 6.2 Theory development

#### 6.2.1 Conditions that influence ownership of learning during small-group work

The pedagogical intentions are to encourage the students to act autonomously to increase the student influence in the classroom practice. The critical aspects are the opportunity to choose the task with regard to level of difficulty and type of task. There are several ways to initiate
small-group work. Traditionally the students work on the same task. One way to increase student influence in their learning situation is to give several tasks with different levels of complexity to choose from. Another way is to give more open-ended tasks and tasks more open to student contribution. The small-group work is one way to give the students the opportunity to create ownership, and it needs strong management to work well. (See table 4)

We started to look for Group Student Ownership of Learning (SOL-g) during the small group-work, the task performance, in which the teacher was responsible for the supply of management and to be supportive of the autonomy of the group. The group is responsible for choice and control of a task and its performance, and for autonomous work.

<table>
<thead>
<tr>
<th>Small-group work</th>
<th>START</th>
<th>DURING</th>
<th>END</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEACHER</td>
<td>Overall management, content responsible, task proposals</td>
<td>Autonomy support, Equipment supply, available as discussion partner</td>
<td>Reviewer, feed-back and response</td>
</tr>
<tr>
<td>GROUP</td>
<td>Choice of task</td>
<td>Control and management of task performance</td>
<td>Presentation of results</td>
</tr>
<tr>
<td>INDIVIDUAL</td>
<td>Choice of aspects</td>
<td>Activities, participation in talk, experiments, production</td>
<td>Activities, participation in talk. Responsibility for some part in the results</td>
</tr>
</tbody>
</table>

Table 4: Small-group work management.

6.2.2 Group and individual student ownership of learning

The question of student ownership of learning emerges or starts from the moment the teacher demands/plans for a content-related activity to be executed, e.g. training in problem-solving of a physics problem, laboratory activity, or other kind of inquiry. There are three fundamental processes included which can be addressed to ownership. The first is the power process; the opportunity and responsibility to take decisions about the task itself and how it is going to be implemented and fulfilled. The second is the management process; how the task is practically implemented and the results presented. Finally, the third is the learning process; how individual constrains and anomalies of understanding or high capacity are expressed and given effort towards during work.
The three processes can be seen in the classroom by looking for the task management and for the individual questions/ideas that are put forward during the task. The opportunity or power process will be underlying 1) how the task will be finally formulated in its details before work, how the management of the task is fulfilled and how the production of the result will be presented, as well as 2) how the individual questions/ideas/anomalies of understanding are expressed and given space during work. The power/opportunity aspect is of importance, not only between the teacher and the group, but also between peers within the group. This is the reason why we distinguish between two dimensions of student ownership of learning – group and individual. SOL-g and SOL-i are united as two aspects of the same phenomenon – student influence on physics learning. The underlying power/opportunity process is an inseparable aspect of how SOL is seen in the classroom and makes them two dimensions of the same phenomenon. Group-activities are, in fact, realised opportunities from the assumption that the starting point for SOL is the task/inquiry from the teacher, and SOL-i is realised opportunities to raise own ideas and difficulties.

Hence, ownership as a theoretical framework is developed by differentiating two dimensions whereby:

1. regarding the groups’ choice and control of the management of the task in a small-group situation; how the task is determined, performed and finally reported.
2. regarding to the start of the individual student learning process that can be analysed on the basis of own questions and own anomalies of understanding.

Figure 5: Three processing underlying ownership of learning
In an instructional setting that includes small-group work, the success of the lesson is connected to the choice of the task; who decides the task, its level of difficulty, and whether it is open-ended or has a specific answer. Can students influence the mathematical level of the task, or the connection between everyday life and real world problems? What are the limits for the performance of the task? How is planning and performance executed and what responsibilities do the students have for making progress, and how is the final product assessed? Does the group take these kinds of actions to make choices and get control? We referred to these issues as the group ownership of learning (SOL-g).

Some choices are not taken by the whole group; they are taken by single individuals in the group. We found that Individual student ownership of learning (SOL-i) means that a single student asks an own unique question that initiates a learning process, recurs and develops, and finally, gives some new insights to the student. For us, the opportunity to choose a task, as in this study with a miniproject, does not necessarily mean that they invent a task themselves, instead is it more likely that the teacher\textsuperscript{14} proposes open-ended tasks, including driving

\textsuperscript{14} (The teacher can be challenged by new views that emerge from the students’ experiences. He/she may be unsure of how to deal with these questions, and has to develop new ideas together with the students. The teacher

Figure 6: Actions of choice and control in group and individual level

In an instructional setting that includes small-group work, the success of the lesson is connected to the choice of the task; who decides the task, its level of difficulty, and whether it is open-ended or has a specific answer. Can students influence the mathematical level of the task, or the connection between everyday life and real world problems? What are the limits for the performance of the task? How is planning and performance executed and what responsibilities do the students have for making progress, and how is the final product assessed? Does the group take these kinds of actions to make choices and get control? We referred to these issues as the group ownership of learning (SOL-g).

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\textsuperscript{14} (The teacher can be challenged by new views that emerge from the students’ experiences. He/she may be unsure of how to deal with these questions, and has to develop new ideas together with the students. The teacher

56
questions, that trigger and elicit student-generated questions, which then become the basis of individual student ownership of learning (SOL-i). This approach of supporting students with teacher formulated tasks, including driving questions, that inspire student-generated questions is used by Crawford, Marx, and Krajcik (1999) in developing inquiry-based learning settings around tasks that are relevant both for students’ everyday life and the educational goals for the science course.

In the second dimension, student individual ownership of learning (SOL-i), the students work with their own learning during the performance of the task, both in a subject matter content perspective, and in a social perspective. The individual student can raise own questions of interest for him/her, because these questions built on own experiences or difficulties in understanding something that is required before the task can be executed.

The observation that the autonomous learner works on his/her own ideas, and is persistent, is important within our iteratively developed categories for individual ownership. It is important for the learning process that the learner creates his own problems and develops his own questions towards new insights. Others emphasise this observation too:

*Support the learner in developing ownership of the overall problem and task... No matter what we specify as the learning objective, the goals of the learner will largely determine what is learned. Hence it is essential that the goals the learner brings to the environment are consistent with our instructional goals... we can establish a problem in such a way that the learners will readily adopt the problem as their own.* (Savery & Duffy, 2001, p.31)

Furthermore, Milner-Bolotin’s (2001, p. 149) empirical finding that student interest in a project topic is of importance for their feeling of ownership, indicates that the students own questions at the start is crucial. Due to the fact that we consider the individual student ownership of learning (SOL-i) to be a process in time, we found this had a striking resemblance to the mimesis concepts developed by Ricouer (1984) from Aristotle’s Poetics. Mimesis is a cyclical interpretative process. As time passes, our circumstances give rise to new experiences and new opportunities for reflection, so we can re-describe our past experiences. The mimesis process describes the way a person has an idea or a view of a phenomenon, and by being exposed to a specific situation, such as by looking at a painting or watching a theatre play or talking to someone, can reach another view of the phenomenon.

also has opportunities to learn from the group’s choice of task, what they are interested in, and what they find easy and difficult in the task. The teacher can also learn how individual students use their alternative conceptions, and find opportunities to challenge their views.
Finally a new insight can come out of the process. The phases in this mimesis- process are named prefiguration, configuration, and refiguration.

6.3 Empirical results about Student Ownership of Learning (SOL)

The aim of this study is to develop the framework for student ownership of learning (SOL) and, by qualitative analyses in case studies, to show how SOL can be seen during small group work in physics within the instructional settings of miniprojects (MPs) and context rich problems with group-discussions (CRPs), in three different physics courses. SOL considers student opportunities to realise influence in the learning environment. Learner autonomy is found to be of importance for students commitment to science in schools. Transcriptions from audio/video-recorded small group work in physics with MPs in a student teacher physics course (2 groups), from an upper secondary school physics course (2 groups), and from CRPs (4 groups) in an introductory physics course at university, have been analysed in depth with categories developed in an iterative and interpretative process using interrater reliability calculations for 5 of the groups.

Categories are developed for SOL in two levels: group (SOL-g) and individual (SOL-i). These categories provide teachers, students, and the researcher with an analytical tool to discuss student influence in classrooms.

<table>
<thead>
<tr>
<th>SOL-g: Group ownership of learning</th>
<th>SOL-i: Individual student ownership of learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>is the groups’ choice of task and control of management of the task; how it is determined, performed and finally reported.</td>
<td>is the work with a question/idea that comes from own experiences, interest, or anomalies of understanding, and that comes back several times leading to new insights (mimesis).</td>
</tr>
</tbody>
</table>

An endeavour to see SOL in concrete learning and teaching situations, empirically, as stated as the first objective, is given in the table where SOL-g is analysed for both CRPs and MPs. The pedagogical intentions are the same for both settings, namely, to encourage the students to act autonomously in order to increase student influence in the classroom practice. The critical aspects are the opportunity to choose the task regarding level of difficulty and
type of task. This opportunity seems to be much higher within the MPs compared to CRPs, due to the fact that CRPs have the best solution whereas MPs are more open-ended and more open to student contribution. In the last data collection, we increased this opportunity of choice and higher SOL-g by letting the students choose between three to five CRPs each session. The students then sorted out CRPs of interest to them for one reason or another: easy task or interesting task. During the execution phase it became obvious how easily that peer groups went into exploratory talks with different themes. This opportunity was seen as SOL-g in both settings. The big difference was the opportunity to control the process. MPs used the whole laboratory and library, and used more time for the project, whereas CRPs had to carry out theoretical problem-solving in a more limited way, and with less time for discussions.

At the presentation phase, the CRPs suffered from too little time to get qualified feed-back to their questions. The design of the tasks could be improved in several ways for both MPs and CRPs. The format that gave total free choice was too time-consuming. Too much time was spent on sorting out what really was in the area of interest for the physics course. In this situation, students in upper secondary school proposed projects that were unrealistic to do in the time-space given, and negotiations regarding this issue showed how much “physics” that is taken for granted when we make tasks.

One or two students in each group were candidates for individual ownership of learning SOL-i, as can be seen in Tables 8 and 9, p. 71. This is an important finding that shows the complexity of the effort to increase student influence in the classroom. The student with high SOL-i put forward questions based in own experiences or anomalies of understanding. This student is not automatically the leader in the group or the one that talks the most. In CRP D-groups (Jonsson, Gustafsson & Enghag, 2006), where the student talk is equally distributed among the students, several students can raise own questions and have input from the others that help this student to continue with the questions towards gaining a new insight. In S-groups, with a strong leader who does the problem-solving almost all on his/her own, it is more likely that no individual ownership is seen at all, because the goal has been to produce a fast solution to the task and not really for new knowledge or learning. In order to challenge S-groups to more creative thinking, teacher intervention is needed with complimentary questions and ideas for activating the whole group.
6.3.1 Group ownership of learning (SOL-g)

The dimension, group ownership of learning, refers to the groups’ choice and control of the management of the task; how the task is determined, performed, and finally reported. The other dimension, the individual student ownership of learning, refers to individual student questions/ideas that come from own experiences, interest or anomalies of understanding, and that come back several times leading to new insights.

SOL-g could be seen as the ownership of the task on group-level, when the students, together with the teacher, decide on the management of the task. In our categories, we looked for student opportunities for autonomy, control and choice. We analysed the small-group work in these directions at the start, during performance of the task, and also during the presentation of the results.

Savery & Duffy (2001, p.32) emphasise that learners must have ownership of the learning or problem solving process as well as having ownership of the problem itself, and are critical towards an instructional design when teachers give students ownership of the problem but dictate the process for working on that problem. This is in line with the view of ownership as a process in time, and in our categories we look for student autonomy by looking for student possibilities to control and student possibilities of choice, at start, during performance of the task and also during the presentation of the results. Indicators are restricted to those of importance for SOL-g, i.e. indicators that matters for the group.

6.3.1.1 Operational definition of group ownership of learning (SOL-g)

(See also Table 5.)

At the start

This category is used to find out how the groups are constituted and how the task is determined.

- choose a task within a content area
- constitute groups with the same choice

During performance

Here we look for the groups management activities and whether they use group discussions with exploratory talks as a help to reach consensus about the performance and about task issues.

- choose plans for work
- control proceedings of the task
- group discussions
The presentation of the results

This category is used to see how the groups’ presentation of their results is completed.

- choice and control of how and what to present as result

<table>
<thead>
<tr>
<th>SOL-g</th>
<th>At start</th>
<th>Performance</th>
<th>Presentation of results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>The group takes actions of choice and control with respect to the task</td>
<td>The group takes actions of choice and control with respect to organisation and content of work</td>
<td>The group takes actions of choice and control with respect to formulation or presentation of results</td>
</tr>
</tbody>
</table>
| Indicators | - choose a task within a content area  
- constitute groups with the same choice | - choose plans for work  
- control proceedings of the task  
- group discussions and/or exploratory talks  
- decide between a theoretical or elaborative way to solve the task | - choice and control of how and what to present as result  
- written or oral |

Table 5: Group student ownership of learning (SOL-g)

To compare the character of the instructional settings in use, namely, MPs and CRPs, an overview of the SOL-g indicators in each instructional settings is shown in Table 6.

<table>
<thead>
<tr>
<th>SOL-g</th>
<th>At start</th>
<th>Performance</th>
<th>Presentation of results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>The group takes actions of choice and control with respect to the task</td>
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| Indicators | - choose a task within a content area  
- constitute groups with the same choice | - choose plans for work  
- control proceedings of the task  
- group discussions and/or exploratory talks  
- decide between a theoretical or elaborative way to solve the task | - choice and control of how and what to present as result  
- written or oral |

Table 6: Group ownership of learning SOL-g realised in MPs and CRPs – a general view.
**Conditions at start**

The intentions in both instructional settings are to encourage the students to act autonomously. However, the MPs idea builds on the assumption that all students individually choose an MP from a list proposed by the teacher, with open-ended ideas for the choice of an MP, including the possibility of a totally free choice of MP within the content area. This condition permits each student to choose from his/her own level and his/her own interest, and also to focus on tasks that are holistic and are more directed towards a real world context understanding than to mathematical problem-solving. Hence, the conditions for ownership are better in MPs than in CRPs, as the groups are constituted with students who share the same interest and goal. With regard to the CRP setting, the tasks are limited to mathematical problem solving. They have to be completely designed in advance by the teacher, and even if they are open-ended, there is, to a certain extent, a best solution to the given problem. The groups are put together based on individual differences rather than similarities.

Originally all groups solve the same CRP. We enhanced the SOL-g by letting the students choose from several CRP tasks. MPs give higher SOL-g than CRPs do at the start. In the examples given below, we followed two groups with high group ownership of learning.

### 6.3.1.2 Example 1: Group ownership of learning

**The Transformer group (miniproject, see paper IV for a full description)**

*At the start*

All members of this group gave a written proposal for choosing this miniproject. Those students with the same choice then constituted the groups. This gave the group SOL-g with regard to the first category as both of the criteria were fulfilled. Their proposal texts were, as follows:

- **Markus:** I am interested in how electric energy is transferred from industry to houses and in how the transformer works. I like to have a holistic perspective on things.
- **Kenneth:** This is something that is used in reality. It could be fruitful to know how a transformer works in a transformer station, for example, and how a transformer station works itself; how current reaches 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 an increasing part of current consumption. I would like to have impact on this in aspects of the environment, and how allergic persons are affected.

**Performance**

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The group showed SOL-g by deciding to start with experimental work in the laboratory as well as using intense group discussions. They formed the design for their study and they made frequent use of group talk, e.g. in the form of exploratory talks, for increased physics understanding and meaning making.

The presentation of the results

The teacher determined that this should be a 10-20 minute presentation in front of the class, including experimental demonstrations. The group showed SOL-g by planning, by themselves, the content and design of the presentation. The presentation had four parts:

- What is a transformer?
- How does the transformer work?
- Practical use of transformers
- The groups’ reflective thinking

The group presented their results orally based on PowerPoint presentations by all group members. Mattias was the leader of the presentation and started with an overview of the presentation design. Markus began with a holistic view of the transformer in society and electricity distribution into households. He also explained a simple mathematical theory of the transformer. Kenneth and Jonas verified the theories by experiments that transform voltage at different settings. Kenneth gave specific contributions about transformers in everyday life. Mattias continued with an explanation of the group’s reflections over energy losses and measurements from their investigation. Their PowerPoint presentation was excellent. The response from the audience was good with questions and discussions. Mattias and Kenneth’s parts of the presentation were clearly related to their own individual questions (see below about SOL-i results).

Thus, to summarise, group student ownership of learning (SOL-g) was high with respect to the choice of miniprojects, control of task performance, and of presentation. The final presentations showed how the groups from an open-ended task had created a presentation of a physics-related topic, and were able to defend this in front of the teacher and the other groups. The way that the group came to this outcome could be described by several decisions the group made on their way (SOL-g), – and also by how the individual students’ own questions had impact on this outcome, and helped to initiate a learning process (SOL-i).

6.3.1.3 Example 2: Group ownership of learning

The “Drink” group (See paper III for details about the group)

At the start
“The Drink” group did not choose this task; it was given by the teacher. The group constitution was also determined by the teacher for the purpose of constituting mixed ability groups. This provided the start for this group with low ownership.

Performance
The group did not make any explicit plans for their activities, but started immediately to discuss the conditions for the task in a constructive way. The group discussions included all members of the group, and they totally controlled the proceeding of this theoretical. The teacher asked them, now and then, if they needed help, and they checked some details with him. The group discussion by exploratory talk was indicative of SOL-g. The equal distribution of talk (student A 27%, student B 27%, student C 22%, and student D 25%, of all counted words in the transcripts) indicated high group ownership. The time-line of activities followed a problem-solving strategy, even if they jumped back and forth in an exploratory way.

The group followed a problem-solving time line for the task, and the task was fulfilled after 38 minutes. The group reported the result to the teacher. The questions that kept the conversation going are listed below:

Identifying the problem
0 - 1 min Discussion about the appropriate temperature of a drink
1 - 2 Content in drink – water or alcohol?
2 - 3 Discussion about the drinks volume.
3 - 4 Can the fluid be anything else then water, when ice is one phase?
   What is start temperature of drink – temperature of the environment?
4 – 5 What is a dry drink?
5 – 6 How differ crushed ice to ice-cubes – cooling velocity?
6 – 7 First modelling formula $Q = c*m*\Delta T$ inserted.
7 – 8 Does the ice melt completely? What happens with the volume then?
8 – 9 Does the specific heat for water change with the temperature?
9 – 10 Are we interested in mass or density?
10 – 11 Can ice be colder then zero?

Start of the modelling, and clarifying the physics of the problem
11 – 12 min As we know the specific heat for ice at -10 C, can’t we use that temperature for the ice?
   Is the mass for 25 cl drink 0,25 kg?
12 – 13 With ice colder then zero, don’t we have to include one more term in our equation?
13 – 16 ’Latent heat’ – what happens when the ice melts?
16 – 17 Discussions about energy, temperature-energy-an own concept, are created
17 - 21 How does the equation change if latent heat is to be included?
21 - 28 Difficulties with modelling and mathematical equation solving

Evaluation
28– 38min What is the density for ice? How do we proceed from mass of the ice to number of ice-cubes? Own evaluation. Reflections.

The conversation in the group developed in two ways: 1) by exploratory talks, in which the students interacted intensively in order to make a decision about a specific topic or 2) by a
‘thinking aloud’ form of conversation that seemed to run parallely as they developed their own individual thinking. These two ways are seen in the mind maps that were performed by the group talk. Fig 3 shows a mind map over the first 10 minutes of the group talk.

Figure 7: Time line for the first part of group discussions for “the Drink Group”

The presentation of the results

The results were reported to the teacher who controlled whether they had successfully solved the problem, but gave limited feedback. They also reported, as group, a written solution after the lecture.

6.3.1.4 Example 3: Group ownership of learning

The Key group: (see paper V for a full description)

At the start

The students chose a task from five different context rich problems. The groups were put together by the teacher. This gave an increased ownership, in comparison with The Drink group, as the choices made increased the groups influence on their learning situation.

During performance
This group used intense group discussions, even if the initiative was taken by “student J”. This group was interesting as we did not find individual ownership within it, despite the fact that this group had group ownership of learning. Their efforts were totally focused on producing a solution to the task, but they did not take time for individual thinking associated with the task.
Figure 8: The flow-chart of the “Key Group TDJ” conversation
The presentation of the results

As for The Drink group, this group had limited SOL-g in this part due to low interaction with the teacher concerning feedback on the work reported.

6.3.1.5 A comparison of group ownership in MPs and CRPs

The intentions in both instructional settings are to encourage the students to act autonomously. The MP groups took different departures for their performance. Some groups mainly carried out literature studies (The Thunder group, The Handbook for teachers – safety with electricity group) but also contacted central authorities outside the school to get information. Other groups performed an experimental study (The Solar Wind group, The Electro-Magnet group, The Electric Motor groups, The Transformer groups). They had to choose plans for their work and they all had control of how the work progressed. They asked the teacher about material supply, and they even brought apparatus with them from home to school and vice versa. The CRP groups also decided how to work, but had no opportunities to do experimental work. Due to this situation, they tried to measure weight and length for the chain (“The Key” group), and used their own chains as an example in the discussions. They also planned for the different steps in their solution, but the theoretical character of the task gave limited freedom to act. All groups used exploratory talks to move forward in their discussions, and distinct exploratory talk themes were detected. The occurrence of exploratory talks was an indicator for high SOL-g. The contact with the teacher functioned best during the performance phase within both instructional settings.

The groups that solved context rich problems did a minimum presentation to the teacher and submitted a written report without feedback if it was accepted as the assignment. The opportunity here for SOL was too low because of the time limit as well as too much pressure to solve another of the CRPs. The presentation of the MPs was, on the other hand, rather time consuming. The students made Power Point presentations or written reports and an oral presentation in front of the class followed by open discussion. The feedback from the teacher was still limited on an individual basis.
6.3.2 Individual Student ownership of learning (SOL-i)

This is a construct that proves that if a student takes the opportunity to revise the question that needs to be answered, and is free to work on the obstacles that he/she might experience, before the student has possibilities to develop his/her understanding further.

6.3.2.1 Operational definition of SOL-i

The individual student ownership of learning (SOL-i) is confirmed if a student has an "own" question/idea that is important to the student (prefiguration), and shows commitment to this question/idea by coming back to it himself/herself, as well as during group work, in significant ways (configuration), and also comes back to this question/idea with indication of development of the question/idea leading to new insights (refiguration). The categories were developed over time, and iteratively improved to describe the situations found. Finally we stayed with SOL-I / Not SOL-I and process criteria/indicators named after the mimesis cycle. (See table 7.)

Prefiguration

- A question/idea appears

This indicator is used to find a candidate for an own question or idea. A student focuses on a specific issue that is connected to the task, but is not the task itself. The question can be observed before the MP or CRP, or at the start of the work. The student makes comments concerning the question/idea. The indicators are seen as: 1) a direct question is asked, 2) a dilemma or anomaly is mentioned that expresses lack of understanding of something in connection to the task, 3) importance or interest of an issue is mentioned and 4) own experiences are discussed in connection to a problem.

Configuration

- The question/idea comes up again
- Actions made on account of the question/idea
- Other students views are considered

This category holds three different ways in which the question/idea can return. The first is if the question/idea comes back again in a more direct way, and this can be detected by looking for: 1) a repeated question or the same question with other words, and 2) whether the student refers to own experiences, after the question is already mention in the
prefiguration. The second is if actions are carried out on account of the question/idea, such as if the student is: 1) doing own experiments, or 2) searching for new information, or 3) creating own material as a direct consequence of the question. The student could repeat his own question with the same or other words: 1) The question/idea comes up again, 2) The student takes initiatives to carry out experiments or starts to gather facts into own files, and 3) Actions are made by the student on account of the question/idea.

There is a third way to find configuration, and that is if the student take impressions from other students’ views, and these are considered. Then the indicators arereferring to peers: 1) experiences, 2) explanations, or 3), information given to him/her.

Refiguration:

- Development of the question towards new insights

This indicator is used if the student shows development towards new insights compared to the question that was earlier expressed. If the question is grounded in holistic understanding, it is more likely to see new insights develop and an indication of the question in the presentation. If the question concerns a physics concept, a conceptual change could be seen. Refiguration does not demand a complete conceptual change in a statement, but it does require: 1) some indication of the question in the result or in presentation, or 2) a reflection with some indication of the question, or 3), a transition from experience to physics understanding.

<table>
<thead>
<tr>
<th>Category</th>
<th>SOL-i</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process criteria</td>
<td>PREFIGURATION (Pre)</td>
</tr>
<tr>
<td>Description</td>
<td>A question/idea appears as a candidate for SOL-i</td>
</tr>
<tr>
<td>Indicators</td>
<td>- A question is asked</td>
</tr>
<tr>
<td></td>
<td>- A dilemma or anomaly is mentioned</td>
</tr>
<tr>
<td></td>
<td>- Importance or interest of a question/idea is mentioned</td>
</tr>
<tr>
<td></td>
<td>- A question/idea is related to own experiences</td>
</tr>
<tr>
<td>Configuration (Con)</td>
<td>- The question/idea comes up again, or</td>
</tr>
<tr>
<td></td>
<td>- special actions made on account of the question/idea, or</td>
</tr>
<tr>
<td></td>
<td>- other students views are considered</td>
</tr>
<tr>
<td>Indicators</td>
<td>- The question/idea comes up a second time, and is connected to the</td>
</tr>
<tr>
<td></td>
<td>prefiguration done</td>
</tr>
<tr>
<td></td>
<td>- Search new information, and/or make own experiments and/or use special</td>
</tr>
<tr>
<td></td>
<td>material, related to the own question/idea</td>
</tr>
<tr>
<td></td>
<td>- Refer to information and/or explanations from others</td>
</tr>
<tr>
<td>Refiguration (Re)</td>
<td>- Reflections or other signs of the question/idea are expressed</td>
</tr>
<tr>
<td></td>
<td>- A transition to physics understanding is done</td>
</tr>
</tbody>
</table>

Table 7: The category for individual student ownership of learning (SOL-i) and the necessary process indicators prefiguration, configuration and refiguration with description

The categories were developed from a fine-grained study of 7 candidates for positive SOL-i and were chosen from 8 groups with 27 students in total.
<table>
<thead>
<tr>
<th>Education</th>
<th>Group name</th>
<th>Number of students</th>
<th>SOL-g Task Start/Performance /Presentation</th>
<th>SOL-i Mimesis Student1/Student2/Student3</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics Teacher Program University (MP)</td>
<td>The Transformer group MKJM</td>
<td>4</td>
<td>Yes/Yes/Yes/Yes</td>
<td>Yes/Yes/No/No</td>
<td>See Paper IV</td>
</tr>
<tr>
<td>The Solar Wind DJ</td>
<td></td>
<td>2</td>
<td>Yes/Yes</td>
<td>Yes/Yes</td>
<td>See Enghag, 2005</td>
</tr>
<tr>
<td>Upper secondary school (MP)</td>
<td>The electric circuits Group ALKC</td>
<td>4</td>
<td>Yes/Yes/Yes/Yes</td>
<td>Yes/Yes/ No /No</td>
<td>See paper II</td>
</tr>
<tr>
<td>Upper secondary school (CRP)</td>
<td>“The Clay” Group ALK</td>
<td>3</td>
<td>Yes/Yes/Yes</td>
<td>No/No/Yes</td>
<td>See paper I</td>
</tr>
<tr>
<td>Aeronautical Engineering Program University (CRP)</td>
<td>“The Drink” Group</td>
<td>4</td>
<td>Yes/Yes/Yes/Yes</td>
<td>Yes/Yes/ No/No</td>
<td>See Paper III</td>
</tr>
<tr>
<td>“The Key” Group AEXX</td>
<td></td>
<td>4</td>
<td>Yes/Yes/Yes/No</td>
<td>Yes/No/No/No</td>
<td>See Paper V</td>
</tr>
<tr>
<td>“The Key” Group CDX</td>
<td></td>
<td>3</td>
<td>Yes/Yes/Yes</td>
<td>No/No/No/No</td>
<td>See Paper V</td>
</tr>
<tr>
<td>“The Key” Group TCJ</td>
<td></td>
<td>3</td>
<td>Yes/Yes/Yes</td>
<td>No/No/No/No</td>
<td>See Paper V</td>
</tr>
</tbody>
</table>

Table 8: Empirical findings of SOL in different groups and references to related papers.

The distribution of candidates for SOL-i within the groups are seen in table 8. Typically one or two students are seen to have SOL-i in each group. One group has no candidate at all.

The candidates for Individual Student Ownership of Learning (SOL-i) are shown in Table 9.

<table>
<thead>
<tr>
<th>Student</th>
<th>Group</th>
<th>Education/Programme</th>
<th>Paper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mattias (MP)</td>
<td>The Transformer Group</td>
<td>Education</td>
<td>IV</td>
</tr>
<tr>
<td>Kenneth (MP)</td>
<td>The Transformer Group</td>
<td>Education</td>
<td>IV</td>
</tr>
<tr>
<td>David (MP)</td>
<td>The Solar Wind Group</td>
<td>Education</td>
<td></td>
</tr>
<tr>
<td>Lena (MP)</td>
<td>The Electric Circuits Group</td>
<td>Upper secondary school - science programme</td>
<td>II</td>
</tr>
<tr>
<td>Student T (CRP)</td>
<td>The Key</td>
<td>Aeronautical Engineering Programme</td>
<td>V</td>
</tr>
<tr>
<td>Student E (CRP)</td>
<td>The Key</td>
<td>Aeronautical Engineering Programme</td>
<td>V</td>
</tr>
<tr>
<td>Student A (CRP)</td>
<td>The Drink</td>
<td>Aeronautical Engineering Programme</td>
<td>III</td>
</tr>
</tbody>
</table>

Table 9: List of students with high Individual Student Ownership of Learning (SOL-i)
6.3.1.2 First case of Individual Student Ownership of Learning (SOL-i)
Mattias (The Transformer group) (See paper IV)

Prefiguration
Mattias already expressed his own question in the first group discussion about possible ideas for miniprojects. His young son had an accident with a small transformer at home. Mattias was surprised that his son could get hurt by a transformer, and was interested to learn more about how the transformer works. In line 62 of the transcription, he expressed his difficulty in understanding the accident that he observed. In line 63, he referred to the experience with his son, and in line 64 he showed interest.

62 Mattias: I was thinking about this... and then I found something I did not understand.
63 Well, the transformer.... it started with my son, he got hurt because of a broken transformer.....and nowadays we have those small transformers all over the place...inside every electric thing...when it is not 230V there is a transformer somewhere –
64 I think it could be fun to think about it....
65 I have thought about it…so I think, …yes, you take the current up and down…

Further on in the opening group talk, when he discovered a miniproject that was connected with transformers, he became excited and immediately wanted to opt for this. In line 129, the two raters indicated prefiguration, but not for the same reason; one was because of the indicator “experience”, and the other because of the indicator “an own question/idea ”. to the meaning of the sentence is read between the lines, but both raters agreed that this was another instance of him showing signs of having an own question/idea that he is thinking about. Moreover, there are only a few words in line 131, so it has to be an interpretation whether they express “interest/importance” or whether it is a reference to “an own question/idea”. Nevertheless, both are indicators for pre-figuration.

129 Mattias: And now 14 (MP Transformer in the list) – by a pure coincidence– I…this one I can think of…the transformer.
130 Kerstin: Mattias – now you….
131 Mattias: Yes, this one I can think of…
132 Kerstin: To illustrate the transformer…..

Configuration
After this first discussion about choosing their miniproject theme, Mattias began working together with Jonas, Kenneth and Markus on the transformer miniproject. During the first lab session, Jonas and Kenneth started experiments with transformers available in the lab. Markus
and Mattias discussed more theoretically how the transformer can be explained with the concepts of physics. Now and then they checked with each other as to how they should all proceed with their tasks. Markus and Kenneth, in lines 334 and 335, discussed the experimental results of Kenneth’s transformations of voltage. Mattias, in line 336, tried to contribute with an unexpected explanation for the result whereby they found less than the expected 20 Volts. He was working on his previous own question again. His question had developed into a hypothesis about energy losses in the transformer causing the transformer to get hot. The indication is that “the question/idea came up a second time, and is connected to the prefiguration done”, thus showing configuration:

334 Markus: The accordance is good here. It is fun to see that it functions now.
335 Kenneth: What is it the reason that we don’t quite get 20V then?
336 Mattias: There have to be losses somewhere.

In the transcript there then follows a long part in which Mattias and Markus discuss the physics of the transformer. They argue about how the magnetic field changes directions, and the basic principle of how the transformation can be explained. Mattias talks about what he has read in literature, and he also refers to his son’s text book from school that has nice and easy explanations about how the transformer works and how voltage transformation is dependent on the number of windings in the coils. This shows that the group is very committed to this task in all its parts, not only to the aspects of Mattias' question.

Later on, Mattias in discussion with the others formulated his hypothesis that there are energy-losses inside the transformer that cause the transformer to get hot. This indicates another move from every-day understanding to a more physics related understanding.

He wanted to measure these losses, and the group decided to buy a new instrument that can measure energy, power, and even energy expenses. They ordered the instrument from the teacher, who arranged for this the same day. This particular action is also a sign of configuration. When Jonas and Mattias began the measurements, Jonas is the one who understood the instrument:

348 Mattias Haha haha. It looks as if you can set it to costs directly …!
349 Jonas Energy price – we don’t have one - what is the energy price – I don’t know that…we don’t have one…
350 Mattias No, but the point is to try to find…. why has it stopped here?
351 Jonas But you have turned off the lamp, haven’t you?”
352 Mattias Is it that terrible? Is it that terrible? Does it have to be that terrible?
Mattias' contributions in lines 350 and 352 are hard to understand at a first glance, but if we look at his contribution in 354, we can see all three statements as evidence that he is developing his original question into the hypotheses that there are energy losses in the transformer, even if not being connected to a bulb on the secondary side. From this perspective, his repeated statements in 352 mean that he has expected much higher measurements of power-input into the transformer. This, again, is a clear case of configuration of his first question. At first his friends do not grasp his ideas. This also provides strong evidence that he really has ownership of this question.

353 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.

354 Mattias Yes, but my point was to show that there are energy losses even when the lamp is off…

Mattias developed the issue further when he suggested taking measurements for a longer time, in order to see better results. Kenneth finally confirmed that he understood Mattias' question, but while the other group members considered it to be a good result to find no energy losses, Mattias insisted on energy losses in the transformer, even if the lamp connected to the secondary side was off.

Mattias finally took the instrument home with him, this particular action also indicating configuration, and he could detect energy-losses in this particular transformer that hurt his son, but not in any other transformer in his home, a circumstance he later reported in his presentation.

Refiguration

During the presentation, Kenneth and Jonas gave practical demonstrations of how to transform voltage and current. Markus then gave an introduction to the transformer in society, and also to the theoretical expressions for transforming voltage and current. Finally, Mattias continued with an explanation of the group's reflections over energy losses and measurements from their investigation. In the transcript from the presentation, 24 of 33 statements by Mattias are marked as refuguration of both raters, in itself an indication of how committed Mattias has been to find a solution to his own question. This gives strong evidence for his student ownership of learning in this situation.

Mattias demonstrated both reflections and transition with respect to new insights in physics during his presentation. In lines 469 – 473, he explained how the group had, through practical
experiments, found that transformers have energy losses because they do not transform 100%, as is assumed by theory. He also related to the others that he was thinking of this because his son had an experience with a hot transformer at home earlier. These lines were categorised as "refiguration" with the indicators "reflection" and/or "transition to physics":

469 Mattias: Then we go to the reflections of the group. Does the transformer change voltage and current without losses?

470 Theory said it should. (Points at Markus formula on the white-board.)

471 In the practical experiments we have seen that this is not the whole truth. There are losses somewhere.

472 These were also some of my thoughts, when I had first found out at home that transformers get warm.

473 I took this instrument home with me (shows the instrument to the class) to measure the power in Watts.

In the next passage, we coded as "individual student ownership of learning (SOL-i)" when he talked about physics and explained three reasons for energy losses in the transformer: eddy currents, resistance in the coils, and hysteresis in the iron. As this is clearly related to his first question and contains good physics thinking, it was categorised as "refiguration" with the special indicator "transition to physics".

477 Mattias: We have a consumption of energy if we have an installation with a transformer, so this is not totally valid (Points at the formula).

478 It depends on different factors. It is partly the coils themselves, as a coil contains wire with some resistance.

479 But you remember, we also have the iron core that gives resistance in the iron if the current changes, and the magnetic field is induced in the core.

480 Also, eddy currents that are formed when the iron is heated.

481 Then hysteresis exists, - that is when the iron orientates itself in the same direction...

482 I think this is called idle running current ... I am not totally sure about this....

483 But it is a cost to keep the transformer running

484 One sees clearly that it is 6W...

Mattias was persistent about his question as to why a transformer can be hot. The question, which had come back several times, was reformulated in the configuration phase (by special actions) into a search for energy losses. In this phase, he then refigurated the question by reflective thoughts of the reason and effect of what he had found. This is high ownership of learning, as all three stages pre-, con- and re-figuration are gone through.
In lines 491-493, his reflections concern the costs that one has to pay for if there are idling currents and the environmental effects of needless energy losses. Theses examples of reflective thinking are signs of his ownership.

491 Mattias: One thought is .. how to get away from this? It costs money!
492 Mattias: Is it like this that all transformer have idle running current?
493 Mattias: Then all transformers with idle running consumption cost money and environmental resources.

Finally, he also expressed that perhaps there was some other reason for his transformer showing these high energy losses, because the other transformers do not do that to the same extent. This reflective validity control is also a sign of transition to physics thinking. He has developed his question from “a broken transformer causes accidents”, to an analysis of reasons for the transformer to get hot. He has discovered eddy currents, and he has discussed if this is general, or a specific phenomena in his transformer. He has searched for materials with different properties concerning energy losses, and at the presentation, he presented new types of materials on the market that decrease the problem. He discussed whether energy losses are an economic problem for a family. He has taken his own question in a Mimesis process towards new insights, and by that he has individual ownership to his learning.

6.3.1.3 Second Case 2 Kenneth’s individual ownership of learning (See paper IV)

Prefiguration

Kenneth showed ownership to his learning too. He expressed interest in the transformer during the group talks before the final choice of MP, and we interpreted this as the prefiguration of his own idea. We interpreted it as: “How to show a real transformer from the real world to other students”. The first indication is in line 228 marked by both raters:

228 Kenneth: Yes, number eight looks interesting… Transform the current… what do we do after that…do we bring a transformer station into the classroom? Laugh.

Configuration

Kenneth brought a privately owned transformer into the lab session to see how it worked in reality. His initiative to bring a commercial transformer with him was grounded in his experience of transformers at his father’s work. In line 230, his specific action of bringing the transformer to school, is a way of saying that the transformer is a real transformer from the
real world, and it comes from the real world because his father works at an automobile firm (line 233). It is a real transformer (from his father), which transforms 220 V to 12 V (line 234). As he has got it from his father, this already gives him some ownership of it. The raters had some disagreement concerning whether these this lines count as prefiguration or refiguration, but both had marked the section as belonging to ownership of Kenneth’s learning. His own idea, which at the start concerned how to bring a transformer into the classroom and to explain how electricity is distributed in society, then grows into a need for a more practical understanding of how the transformer works. In line 236, Kenneth discovers that there are lots of technical details to be found in a transformer from the real world, and in line 238 he is interested in understanding this commercial transformer, but he cannot see the coils in this real world transformer.

230 Kenneth:   Well, I brought this one for you….if someone wants to investigate it next year too.
231 Teacher:    Yes, that’s great…
232 Kenneth: I got it from my dad.
233 He works in a car firm, you know, and they expose car stereo apparatus.
234 Then they take 230V and make it 12V for the car stereos.
235 Teacher: Yes,ok.
236 Kenneth: But it is not only the coils and magnets it is a thousands of other things too…
237 Teacher: Well yes, this is a rectifier …mm…that is interesting of course...
238 Kenneth: Yes. Unfortunately you can’t see the coils.

Later on he comes back to his interest in other technical applications of the transformer in the real world: The real transformers are transforming 400 kV to 380 V, see line 342 -345.

342 Kenneth: Isn’t that exactly what happens in a real transformer out there?
343 Kenneth: Because these lines are for 400kV, aren’t they?
344 Mattias: Yes
345 Kenneth: And in some way 380V is distributed to the households, and that must have been by a number of transformations…this is the way you can show reality.

Refiguration
When Kenneth and Jonas showed experiments during the presentation, they transformed voltage and current, but Kenneth also came back to his own question, the use of real transformers. He told the others about the commercial transformer he brought to school. He
explained, in a confident manner, his new insights of how physics understanding can explain how electricity works, and he found a reason why we bother to transform, due to transport energy losses. He understood the use and the function of the transformer. He had ownership of his learning through the opportunity he had of letting physics understanding grow by the development of his own question at the start.

448 Jonas: When and why do we use transformers? We use them everywhere. For lamps and...

449 Kenneth: (interrupts Jonas) We use them to get less transport losses in our lines through the country.

450 Jonas: And we use them at home too.

451 Kenneth: Well, it is mostly 400 kV in the lines that go through the country, but when you reach a real transformer you transform it down and finally it will be 230 V.

6.3.1.4 Third case of Individual Student Ownership of Learning (SOL-i)
Daniel (The Solar Wind group) (See paper VI)

Prefiguration
During the introductory group-discussions of miniprojects, both John and Daniel mentioned their interest in the magnetic field.

John: I think this magnetic field is cool, as she talked about eddy currents...
Daniel: But the magnetic field of the sun... They say that the magnetic field from the sun is so strong that specific sunspots can knock out all nets on earth, and it does in Canada and in the Nordic countries, it has knocked out a whole power plant. I don’t understand it all, but it is interesting..

Daniel expresses a specific unique question; how the sun can have impact on a power plant (Own question). He does not understand this (Anomaly), but it makes him interested (Importance/Interest). He tells about his own experience from a situation in the USA that he has experience of, or heard stories about. He expresses interest in this question, and also that he has a lack of understanding here. The question is in fact already expressed already before the MP is chosen. This makes it a strong indicator for ownership by own question.

Configuration
They started their experimental work by determining the horizontal component of the earth’s magnetic field. During work, Daniel’s question about the overloaded power plants recurred. 

Daniel: I like this one too... And this is what’s preoccupying me That is, that I’ve not seen as many people without electricity.....oh strong as count...it induced “power” that overloaded the system....

John: Yes, exactly, it was induced in the cables then ...

Daniel: Because they are so big and practically go across the whole area and here comes this powerful magnetic fraction sound and it ....couschh....that is a powerful...

Daniel and John had then finished the first experimental part of the miniproject. Daniel had also gathered information from books and the Internet about the solar wind, and showed this to John. He discussed with John plausible reasons for the phenomenon of damaged lines from power plants. The question recurred but this time as a physics inspired question about electric induction.

John: Yes, maybe, couldn’t it be sparks in ....?

Daniel: Yeah, that has happened before....

John: few weeks.... therefore, it will be so hot that it twists itself or...?

Daniel: Yes, something like that....probably caused by........

John: But this hasn’t happened so much in Sweden, has it? Is it mostly in North America?

Daniel’s hypothesis is that induction has been caused by fluctuations in the earth’s magnetic field.

Refiguration
During presentation of the miniprojects the question recurs again.

Daniel: This is VERY interesting! It maybe hasn’t got so much to do with the task but let’s see it as a BONUS. But when the Sun has the big magnetic storms in connection with the Sunspot Cycle, - they come every 12-year. There is such a great magnetic flux from the sun to the Earth so the power net gives current back and the whole net can be overloaded. It happens now and then! It happened in Canada; almost all electricity in Canada was wiped out...
Daniel pointed out how interested he was to discuss this issue: – why does the power plant get damaged and what is the connection with magnetic field fluctuations. He once again described his views about the causes of the damage.

**How Daniel’s ownership had impact on the group.**

He was often involved in exploratory talks with John. He developed his questions through discussions about the Corona of the sun, and by introducing the physics concept induction to explain the current in the lines. His competence development in physics is seen as the insight that the magnetic storms caused induction in the lines; an increased conceptual and contextual understanding.

He showed in the physics test that he already had some knowledge about the physics behind the Northern lights, but John had no idea about the reason for this in the test and because of Daniel’s SOL, John developed his knowledge here.

John had mentioned a general interest on the subject of magnetic fields and eddy currents at the start. He did not have a specific question at the start, and due to that, he had no SOL at the start. He was a strong companion in the exploratory talks that gave Daniel the insights of how induction causes the damage to the pipe-lines. It seems as their development of competences are twisted, the discussion gives them enhanced learning.

In this miniproject Daniel has shown ownership by working with his question about what causes the power-plant damage in Canada. He had experiences of his own that made him curious, and during a miniproject concerning the earths magnetic field he developed understanding by exploratory talks with his partner, John. He repeated his question and developed the question in the phase of configuration. He searched for new information, presented his results in power-point presentation, and could show development of conceptual and holistic understanding of the phenomena. A refiguration has taken place. In fact he also brought another question in, about what the northern lights are, and this led to learning, especially for John, who did not have previous knowledge about the phenomena behind aurora borealis.

Daniel: The Aurora
John: The Northern Lights?
Daniel: Yeh, well we can take up this as power lines
John: Is it the Northern Lights?
Daniel: It’s not really the Northern Lights that causes this, it’s the magnetic flux from the sun that comes and crashes into the power lines and induces high currents that overload the systems and causes them to break down.

Daniel: ....mmh...and that is directly caused by solar winds

John: solar winds

Daniel: and ----the oxygen and nitrogen...and that’s where you get the green and the red

John: Oh yes, because it’s different ....you said that we’ll leave it until....

Daniel: (quotes from a book:) here colour---(inaudible) -- interaction between the electrons in the solar wind that happens in the ionosphere

In this case, Daniels experiences are mentioned in the presentation:

Daniel: When the Sun has it’s 12-years cycle, in 1989 it just happened to be a maximum, there are a lot more magnetic storms and, simply, more particles. They come in and collide, pretty decent, then the northern lights go down almost to the equator and come up from the south poles too. I remember this, because it was my first trip to Sweden, yes I remember it well! There were huge storms with the sun coming out. You could see the northern lights very clearly, I remember in the airplane on the way to Sweden - it was amazing- what a SHOW - light everywhere!

4.3.1.5 Fourth case of Individual Student Ownership of Learning (SOL-i)

Student A (CRP The Drink) (See paper III)

Prefiguration

Student A prefigurated a question that was developed from his experiences of the dry drink. This question is clearly expressed in this excerpt:

Student A: We can’t take too many ice-cubes….then the bottle might freeze.

Student D: (laughs politely at A’s comment)

Student D: How many ice-cubes are needed to...(reads the task loud once again)

Student A: It is a catch question...because the more ice-cubes..

Student B: (interrupts) the bigger the volume it is…

Student A: if we only have one ice cube it will be a damned lot of water in the drink…

Students C&D: No ...but no...
He started in his every-day experience of a ‘dry’ drink, a drink that contains no water, but, as he said, it can be so cold that there is a risk of the bottle freezing. He also expressed an anomaly of understanding this problem, because according to his opinion, the more ice the colder it will be, but there will also be less water.

**Configuration**

He comes back to his question again;

Student B: The more ice the more water it will be...

Student A: …because if you like to have a dry drink you have to have a lot of ice, it gets cold faster, but then it will not melt.

Student B. …umhf..

Student A: The ice stops to melt somehow…if you have enough ice it will not melt….

Student A did not get any support from the others and started to read in his physics book. The next time, when he tried to get into the conversation, he had found a connection to physics explanations of the phenomena of melting. We consider him to have used his experiences of the dry drink to frame the task and to understand the problem.

**Refiguration**

Student A found it troublesome that with a lot of ice, the ice-cubes would not melt and there would be no water added to the drink. He did not express that all the ice would have to melt if the drink would finally stay at 8°C (if it is well stirred, anyhow), nor that they needed to make the problem simpler by thinking of the drink as a mixture of water-ice, to get a problem that they could find a solution to. There is also a possibility that he never thought of the drink as coming into the temperature- equilibrium before it had finished. However, this dry drink experience triggered his curiosity to find a deeper understanding – how can it be related to the drink temperature. Student A started to read in his physics book, and came back with new ideas. He read in his textbook about how a substance changes its phases, and immediately became aware of the connection between the physics he had recently studied and this task about the ice-cubes in the drink. They were are thinking-aloud the 7th minute after reading in their text-books, but now student A could see the connection:

(They all read in their books)
Student D: was it 4.90 4.91 or something…
Student C: one has to have the latent heat
Student A: At phase changes (reads loud of his book)...
Student B: If the system is isolated...
Student A: ...but this is phase change like this..
Student B: then we have to include m times l too...
Student D: But what do you assume? Is it that you put the ice in and it melts away, or is it that the ice only makes it colder...and doesn’t melts...

At this point, Student A got a much stronger position in the group, and the others listened to what he had to tell them. They agreed with his argument to look at the ice as water with the temperature zero, but still there was confusion about the energy for melting the ice. Student C felt that they had to add something, but Student A somehow included both melting and increased ice-temperature into his thinking. The reading of only his statements shows his physics thinking:

Student A: If we look at it as a fluid with the temperature zero after it has come up...
Student B: That’s exactly what we have to do...
Student A: ...but with the same mass as the ice....
Student D: ...exactly..
Student B: It is nothing that disappears.
Student C: We have to do some little Q plus (points on the white-board) here, I feel...
Student D: yeh...something
Student A: Then we will get the smallest amount of ….smallest amount of ice that is needed for the temperature to raise, and when it is all melted, it has become water.
Student D: Yes, I am prepared to agree on that (nods towards B).
Student A: it becomes more of a physics problem so to say...
Student C: add....here the energy that is plus....the one that is zero degree..
Student A: Divide it into two, one that is melting and one that increase from zero to eight!
Student C: ...It gives ...it sucks energy...
Student B: Both then..., and this one....I think it adds first coldness….but continues to add when it goes from zero to eight
Student A: It is just the other way round, it becomes colder and by that it takes energy away. They take energy away. It must be the drink that adds energy to the system with the 20 degrees the drink had.
We contend that Student A in this situation developed his own learning from the idea with the dry drink as a prefiguration. When the question was expressed once again it became a configuration and, finally, a refiguration when he realised the connection with phase changes and recognises the physics explanation for the phenomenon.

6.4 Method development

The development of a methodology within which the work will take place was one of the areas of significance for the thesis. In consistency with the first objective to develop categories which allow us to see SOL in concrete learning and teaching situations, an iterative method to develop categories was used (Niedderer, 2001). Multiple case studies where positive and negative individual utterances were scrutinised gave foundation to several category systems that were revised until none of the further revisions gave results in the data. Interrater reliability calculations were used for inter-subjectivity in the results.

6.4.1 Conversation analyses

The conversation analyses made in this work are based on the framework that Barnes and Todd have developed. (See Chapter 4.2.) However, a modification of their discourse moves is used (See Table 10). These exploratory talk “themes” are used to identify candidates for Individual Student Ownership of Learning (SOL-i) in all case studies. The categorisation of the discourse moves invite – extend – qualify identified the individual’s utterances in the conversation.

<table>
<thead>
<tr>
<th>Move in the conversation:</th>
<th>Invite or request</th>
<th>Repeat and Extend</th>
<th>Answer or Qualify</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description:</td>
<td>Inviting or eliciting another group member into the discussion by asking or turning to him/her encouraging them to take over the discussion</td>
<td>Repeating an important word to keep up and extend the discussion</td>
<td>Answering an earlier hint or express an opinion on a topic discussed earlier</td>
</tr>
</tbody>
</table>

Table 10: Discursive moves found in the exploratory talk parts of the conversation.

6.4.2 Time-lines and flow charts

In order to find a way to open up the data for the second objective, and to see how the conversation developed during work individually and as discourse, two main tools were used, namely, “time-lines” and “flow charts”. The time-lines (See Table 11 for an example.)
provided us with the opportunity to discuss and agree what really took place in the conversation. Flow charts (see Figure 7, p.65 for an example) made the visualisation of the exploratory talks possible with the different steps: initiative, extending, and answering. This also provided an opportunity to reflect on the third objective, the relation between ownership and communication. By comparing the categorisation with ET and SOL-g and SOL-i, the final insight was gained; that ETs are indicators for SOL-g and also that ET often promotes the mimesis-cycle in SOL-i.

<table>
<thead>
<tr>
<th>Analysis of the time-line of the conversation in the group talk CRP “The Drink”.</th>
</tr>
</thead>
<tbody>
<tr>
<td>The group follows a problem-solving time line for the task and the task is fulfilled after 38 minutes. The group reports the result to the teacher. The questions that keep the conversation going are listed below:</td>
</tr>
<tr>
<td><strong>Identifying the problem 0 - 9 min</strong></td>
</tr>
<tr>
<td>0 - 1</td>
</tr>
<tr>
<td>1 - 2</td>
</tr>
<tr>
<td>2 - 3</td>
</tr>
<tr>
<td>3 - 4</td>
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<td>4 – 5</td>
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<td>5 – 6</td>
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<td>6 – 7</td>
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<td>7 – 8</td>
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<tr>
<td>8 – 9</td>
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<tr>
<td>9 – 10</td>
</tr>
<tr>
<td>10 – 11</td>
</tr>
<tr>
<td><strong>Start of the modelling, and clarifying the physics of the problem</strong></td>
</tr>
<tr>
<td>11 – 12</td>
</tr>
<tr>
<td>12 – 13</td>
</tr>
<tr>
<td>13 – 16</td>
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<td>16 – 17</td>
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<td>17 - 21</td>
</tr>
<tr>
<td>21 - 28</td>
</tr>
<tr>
<td><strong>Evaluation</strong></td>
</tr>
<tr>
<td>28– 38</td>
</tr>
</tbody>
</table>

Table 11: Example of a time-line (analysis of the time-line of the conversation in the group talk CRP “The Drink”, see paper III or p. 65)

This provided the opportunity to visualise the activity of different students and to obtain information of how the group functioned, e.g. whether all students were involved in the discussions. One example is “The Key” group where one student is not engaged at all. See Fig 9 below.
Figure 9: See Paper V: APPENDIX 1: The three exploratory talks between three of four students in The Key Group A.

The analysis of how conversations in the group developed showed a complex pattern with exploratory talks as well as self reflective individual reasoning, where one student followed his own question and developed his ideas during the session. The conversation included exploratory talks when the group needed to take decisions about circumstances that were not completely given in the underdetermined task, e.g. when they started to negotiate and to explore, immediately, the value of an appropriate temperature for a drink.

The conversation also included parts where the students developed their individual strategy of meaning making to grasp the problem by talking aloud with no direct response from the others. In both parts, some specific ideas were related to the students’ everyday-life experiences. The opening minutes where the discussion contains everyday-life-experiences were of great importance for the students’ meaning making and understanding of the physics involved in the task. (See Paper V).
6.4.3 Experience-based sentences in conversation during small-group work

The interplay between subjectivity and intersubjectivity, which lies at the heart of this thesis, tries to emphasise the individual aspect of group work. In an attempt to investigate how experiences are referred to during problem-solving, we (See paper III) categorised the utterances in the group conversation into three variables that we found as indicators for our theoretical concepts. Every statement was sorted individually by two of the researchers into “everyday-life-experience-related (E)”, “physics-related (P)” or “remaining(R)” statements. At the beginning of the conversation there are more everyday-experience-related statements than there are physics-related statements, but after 5 minutes the conversation has turned almost totally to physics concepts. [See Paper III, figure 3. The number of statements categorised as experience-grounded or physics from a video-filmed group-talk (double-categorisation made by two researchers). Counts for every five minute periods are given.]

When the students start to discuss the CRP, they have different starting points for their endeavours to become involved in the problem-solving. Student B makes the first statements about the task. He says that they probably need only one ice-cube to start with for the drink to be cool enough, and that $5^\circ$ C is an appropriate temperature, as it is ‘fridge-cool’.

Our variables can, thus, be exemplified by some of the utterances in the conversation.

<table>
<thead>
<tr>
<th>Variable/Category</th>
<th>Everyday-life-experience-related (E)</th>
<th>Physics-related (P)</th>
<th>Remaining(R) statements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Refers to experiences or values given from real-world context</td>
<td>Refers to physics law’s or physics concepts</td>
<td>Neutral comments without reference own experiences of real-world phenomenon or physics concepts</td>
</tr>
<tr>
<td>Example 1</td>
<td>“a mixer gets ‘frost’ on the outside”</td>
<td>“one has to have the latent heat”</td>
<td>“No ...but no...”</td>
</tr>
<tr>
<td>Example 2</td>
<td>“That is as cold as in a fridge...”</td>
<td>“…but this is such a phase change..”</td>
<td>“Yes, I am prepared to agree with that”</td>
</tr>
</tbody>
</table>

Table 12: Categories developed to distinguish between everyday life related statements and physics related.

The two researchers’ judgements are indicated after each statement:

9 B: yes, what is an appropriate temperature R,R
10D: five degrees. That is really cold E, E
11B: That is as cold as in a fridge... E, E
An interrater reliability test was made on this categorisation and the result of the two researchers’ first categorisation was a raw agreement index for the two researchers’ observed proportion of overall agreement of .73. This means that the two researchers made the same categorisation of the statements relating to experience, physics, and remaining, in 73% of all statements categorised. Taking each category separately, \[ R_{category} = \frac{2A}{2A + B + C} \], the interrater reliability for the “E” category was .83 and for “P” category, .88.

### 6.5 Pedagogical findings

Some pedagogical shortcomings were observed in connections to CRPs:

- it is problematic to make calculations in a group, there is a tendency for one student to force the others’ thinking
- one student can stay silent without participating without the teacher noticing this
- the final presentation does not represent all the discussions the group had and some difficulties remain unsolved
- if nobody is skilled enough to model the problem, the intervention of the teacher is necessary – and the teacher has to be observant in the early stages before too much time is lost

Some pedagogical observations in connections to MPs:

- The students prefer broad projects and avoid mathematical problem-solving. The students prefer broad MPs because they need improved understanding of how physics can be seen in real world contexts.

On the other hand, however, we did find benefits in both instructional settings:

- students use each other as a resource and take the opportunity to discuss what they need, e.g. converting units, discussing physics concepts – in fact, they teach each other, act autonomously, and are supportive towards each other
- by focusing on individual lack of understanding, the group supports individual understanding as the students dare to ask “stupid” question without risk
the group finally produces an acceptable solution – even if one student couldn’t produce this solution by him/herself

Some pedagogical observations in connection with SOL

- The findings show, with respect to pedagogy, that MP gives high SOL-g at the start but the CRPs are more teacher-determined.
- Exploratory talks are used for meaning making during performance in both instructional settings.
- Several cases are shown of how everyday life experiences are taken as a starting point for problem-solving that leads into physics reasoning.
- The presentation could, in both settings, include more feedback opportunities for the students.
- Typically, one (or two students) in a group has high SOL-i, and influences the others to also have better commitment to the task to be fulfilled.
7  Summary of results according to the three objectives

The critical aspects of student influence during small-group work was found to concern the students’ opportunity to realise choice and control during the implementation of the task.

7.1  About student ownership of learning (first objective)

The first objective was to develop, theoretically and empirically, categories to sharpen the concept of ownership (see p. 45); how is "ownership of learning" seen in the classroom? The character of SOL has a tension between an ideal and a realised situation. Ownership of learning, together with the concepts of experience and mimesis, is an example of a dynamic or an active concept that has starting point, content, and direction. A first result is that this concept was differentiated into two parts: group ownership of learning (SOL-g) and individual student ownership of learning (SOL-i). This was developed theoretically, based on literature, and tested in eight cases of group work and seven cases of individual students (see p.58).

The question of student ownership of learning comes up, or starts, at the moment the teacher demands/plans for a content-related activity to be executed, e.g. training of problem-solving of a physics problem, a laboratory activity, or other kind of inquiry. There are three fundamental processes included which can be addressed to ownership. The first is the power process: the opportunity and responsibility to take decisions about the task itself and how it is going to be implemented and fulfilled. The second is the management process: how the task is practically implemented and the results presented. The third is the learning process: how individual constraints and anomalies of understanding, or high capacity, are expressed and have effort put into them during work. The three processes can be seen in the classroom by looking for the task management and for the individual questions/ideas that are put forward during the task. The opportunity or power process will be underlying 1) how the task will be finally formulated in its details before work, how the management of the task is fulfilled and how the production of the result will be presented, as well as 2) how the individual questions/ideas/anomalies of understanding are expressed and given space during work. The power/opportunity aspect is of importance, not only between the teacher and the group, but also between peers inside the group. This is the reason why we distinguish between two dimensions of student ownership of learning – group and individual. SOL-g and SOL-i are united as two aspects of the same phenomenon – student influence on physics learning. The underlying power/opportunity process is an inseparable aspect of how SOL is seen in the
classroom and makes them two dimensions of the same phenomenon. Group-activities are, in fact, realised opportunities from the assumption that the starting point for SOL is the task/inquiry from the teacher, and SOL-i is realised opportunities to bring up own ideas and difficulties.

In an instructional setting that includes small-group work, the success of the lesson is connected to the choice of the task. Who decides the task, its level of difficulty, and whether it is open-ended or has a specific answer? Can students influence the mathematical level of the task or the connection towards everyday life and real world problems? What are the limits for the performance of the task? How are plans and performance executed and what responsibilities do the students have to make progress, and how is the final product assessed? Does the group take these kinds of actions to make choices and get control? We refer to these issues as the group ownership of learning (SOL-g).

Some choices are not taken by the whole group; they are taken by single individuals in the group. We found that Individual student ownership of learning (SOL-i) means that a single student asks an own unique question that initiates a learning process, recurs and develops and, finally, gives some new insights to the student. For us, the opportunity to choose a task, as in this study with a miniproject, does not necessarily mean that they invent a task themselves. Instead, is it more likely that the teacher proposes open-ended tasks, including driving questions, that trigger and elicit student-generated questions, which then become the basis of individual student ownership of learning (SOL-i). With individual student ownership of learning (SOL-i), the question was mainly how we can determine whether a student has high individual ownership. It was an important step of research to understand that SOL-i is not "given" like a product at the beginning of group work. It develops like a process. A student does not "have" ownership at the beginning, he/she gains ownership to a question or idea by coming back to the same question/idea several times during group work, perhaps developing it further in a mimesis process (see p. 38). This idea is also the basis for the defined categories for SOL-i: Can we detect an own question/idea, which is coming back several times during group work, and which can be coded as the same by different coders. By iterative procedures, we finally reached about 80% interrater agreements. Consequently, there is some progress with defining individual student ownership of learning (SOL-i). The unit of analysis has been each statement in the transcripts. Empirical findings show that the group has SOL-g but only one or two students show SOL-i. Is it possible to increase SOL-i to more students?
Figure 10: SOL-i is not available to all students in the group even if the group has SOL-g, typically one or two students has SOL-I, but all groups have SOL-g.

7.2 About conversation in group work (second objective)

The second objective was to clarify how the conversation develops during work individually and as discourse. The analyses started with time-lines and flow charts of the conversation that gave as a rough picture of what was going on. Already in that stage we could see if the amount of talk was uniformly distributed among the students (D-groups, discourse-groups) or if one student did all talking (S-groups, single-groups) (Jonsson, Gustafsson, Enghag, 2006).

The categories of exploratory talks as discourse moves from Barnes and Todd were modified after our empirical findings and used to follow individual patterns within the group. These moves facilitated for as to draw the flowcharts to have an over-view from these complex discussions.

It was clear that the students started to open up the task with a discussion that took departure from their own experiences. Some of these “peculiar” experiences gave “student-generated questions” in the mini-projects as in Mattias case when his experience of a hot transformer became a driving force for the group to investigate the different reasons for a transformer to become warm at all, (See Paper IV or p.72) or Daniels experiences of stories where power plant accidents were associated to the Solar Wind (See p.80 and Paper VI).

Also in CRPs we saw this opening from experiences, typically with student A in the CRP the
Drink talking about a dry drink with a lot of ice but no water in it. So, individually some of the students took the opportunity to start from their own experiences or anomalies of understanding, and use the peer group as speaking partners to learn more.

Spin-off effects of these openings were that the group started immediately, and often with practical experiments to get back to bases (MPs) and to determine the border conditions that was not given (CRPs). And new questions could come out from the starting ones. As a group the focus was to deliver a solution to the problem or a final report of the project. This was sometimes done without any sign of learning new, more by using competencies already in the hands of the students.

7.3 About how student ownership and communication are related (third objective)

Exploratory talks were found to be dependent on the learning environment. Exploratory talks took place almost immediately that peer groups were constituted, and this was seen an indicator of group ownership of learning (SOL-g). However, the initiatives for all exploratory talk themes that occurred during a session could be located to one person or to several, e.g. in “The Key” group B, whereby student T was responsible for most of the exploratory talks, but in “The Drink” group, theses initiatives were much more equally distributed. These circumstances had impact on the SOL-i. If a student took initiatives for an exploratory talk, it often took departure from his/her own everyday life experiences or anomalies of understanding. The students that took initiative for the exploratory talks themes were easy to identify from the flowcharts and to analyse for student individual ownership of learning (SOL-i). Cooperative groups used exploratory talks to produce results, but if the initiatives for the communications weree based on individual questions/ideas, individual learning processes could start. A student then referred back many times to the same idea and developed new
understanding and new insights.

Objective 1: Develop theoretically the concept student ownership of learning (SOL) and develop empirically categories which allow us to see SOL in concrete learning and teaching situations.

Objective 2: How does the conversation develop during work individually and as discourse?

Objective 3: How is ownership and communication related?

Student Ownership of Learning (SOL) has two dimensions: Group (SOL-g) and Individual (SOL-i); constructed from empirical data and theoretical findings.

Flow chart of the conversation elucidates the discourse and individual development can be followed. Groups develop differently. Successful groups use exploratory talks.

Exploratory talks are found to be indicators for a learning process. It is part of the SOL-g to have group-discussions. Exploratory talks often promote (mimesis) in SOL-i.

Figure 11: Development of the theoretical approach student ownership of learning
8 Validity and generalisability

Science Education Research (SER) is a social science, and the research is grounded in empirical data that has been observed from a chosen perspective and scrutinised from a specific theoretical base. The goal is not to give a practical recipe for actions but to make us aware of the consequences and the values that go behind the observed reality. Logical structuring of the observations of the empirical reality is a way to produce knowledge. According to Weber (1904), one of the goals of empirical science is to always raise claim of validity and to point out the gap between argument that turns towards feelings and argument that turns towards structuring the empirical reality15 (Weber, 1904). A guarantee for this rational valid structure of the empirical reality is intersubjectivity16; everyone who wants to, and has interest, should be able to follow the logical structure in the study. Qualitative studies benefit from validity categories reformulated from quantitative research (Maxwell, 1996). I give my own view of the descriptive, interpretative and theoretical validity of my study below and discuss the generalisability.

Descriptive validity

Descriptive validity asks if the description of the research is factually correct. This study takes data from three different data collections. Transcripts are made from audio tapes in the transformer group lab session and from video-tapes of their presentation. I was present in the room when the recording was undertaken. I made the transcript myself, and as I knew the students by name from earlier teaching, I could easily distinguish their voices in the audio tape. The audiotapes were in my first study analysed by a CBAV (Computer Based Analyses of Videotapes)- method, i.e. the conversation was arranged into categories every 30 seconds. (See papers I and II). By this, I “knew” the audio-tapes very well, and selected interesting parts for further transcription.

The video-films in the CRP-groups were recorded by myself and my colleagues who were also co-writers in the papers I, III and V. The video-tapes were discussed and summarised first of all in time-lines, and those with high technical quality recordings of the groups were selected for continuing with and transcribing. These time-lines and transcript were discussed and compared several times, as well as discussions about whether we disagreed about who was talking in a discussion had enhanced the quality of the transcripts. The transcripts were

15 ibid, p.99-101
16 ibid, p.107
carried out by me, and I improved my technique to make the transcription in accordance with the transcript symbols given in p.51.

The flow charts were made from the time-lines and from the analyses for exploratory talks and exploratory talk themes. I developed this method in an attempt to visualise the complex conversations, and it became a nice instrument to give a correct overview of the conversation without getting swamped with detail. These have been revised after discussions with colleagues bettering order to improve them in accordance with the transcripts and the videotapes.

The teaching material that was used was also representative and used as course material in the three different courses where the study took place. Some of the transcripts are given as an appendix in this thesis, and excerpts are given in all of the papers. The computer programme used is Excel Spreadsheet and Cmap Tools (Cmap tools is available for download at http://cmap.ihmc.us).

**Interpretive validity**

Interpretative validity asks whether what I interpreted in my observations is representative for what took place between the participants in the group. My selection of problems within this research area was chosen totally subjectively. This subjectivity is not problematic, but it is important that other people can follow the logic in my reasoning, and that my constructed concepts are found to describe the observations from the data in a logical way.

The iterative process between theory development and meaning making of what really took place in the transcripts have to be subjective; this subjectivity is due to the fact that my experiences and background, as the person that I am, interacts with the data and makes me see what I see. The fact that the category system for SOL emerged in different steps that were refined again and again is a guarantee for high interpretative validity.

One question here might be whether I changed my interpretation between the first and the last case. As I went back to all cases several times, I find my interpretations also to be valid with respect to this aspect.

**Theoretical Validity**

I started the study based on a search of relevant literature concerning studies on ownership of learning, and during these five years, the research literature has increased rapidly. I am convinced that my theoretical background are based on sound research as it is accepted by the research community. However, I immediately felt a need to improve the theoretical
framework from the reported research, as there was not a clear unit of analysis, the group or the individual student. The reported studies also covered different subject matter, from both formal and informal settings, and they covered different ages of students. The core observations made in theoretical papers, together with my empirical findings in my own groups, has strengthened my view that the concept of ownership has a tension between an analysis tool and a realised situation of student influence. The category system that finally emerged has been checked with interrater agreement calculations that guarantee some inter-subjectivity. The utilisation of my supervisors here as second raters was for pragmatic reasons. During the whole process, the findings have been discussed and revised after comments from reviewers, research colleagues at my university, and in the project-group at Umeå University.

**Generalisability**

This kind of subtle description demands very fine-grained analyses, and it is not easy to make many analyses at the same time, due to the workload involved. Can the account then be used to make sense of other situations and in other instructional settings? One test of this is to follow the logical consequences of the dimensions. SOL-g and SOL-i are united as two aspects of the same phenomenon, – student influence to physics learning. The underlying power/opportunity process is an inseparable aspect of how SOL is seen in the classroom and makes them two dimensions of the same phenomenon. In fact, group-activities are realised opportunities from the assumption that the starting point for SOL is the task/inquiry from the teacher.

If the small-group, which normally includes 2-4 persons, collapses into one individual, two dimensions are still relevant. If this student has influence and realises the influence in the task, he/she has SOL-g, and if he/she starts his learning process with own questions then he/she has SOL-i. I find this theoretically correct. The lonely student will, however, have limited SOL-g, as no group discussion is possible – this is an epistemological standpoint taken and if a student cannot discuss with anyone it is unlikely he/she will be successful with his/her tasks. If the small-group expands to the whole class, SOL-g will be limited because of the choice. Opportunities will, in practice, be too complex to handle as well as SOL-i. This, perhaps is a better argument than to reduce SOL to small-group work only.
Another tests of this is, of course, if it works when used. Analysing your own classroom to see if the students have opportunity to realise choice, control, and communication is easily done.

- Who determines the task, and what kind of freedom is the task given?
- Do the students have some influence of the performance, and are they free to discuss the task themselves?
- Is there some kind of interaction connected to the presentation?
- What is the character of the group work? Is it to produce a fast answer that is of importance for the group, or do they try to figure out some learning based on their own difficulties and experiences?

It is also possible to listen to the conversation to:

- find student-generated questions that seem to be related to one of the student’s experiences or difficulties.

It is not my intention to say how teachers should act to promote student influence, but I think it is possible that the study can contribute to enhanced awareness of student influence in the classrooms and some indicators of importance. If this is the case, then the study has generalisability.
9 Discussion and Conclusions

In line with regarding physics as a discipline-culture, physics education can also be seen as a discipline-culture. At the core, there are ideas that have a bearing on education in society and on subject matter contents. The main body consists of the on-going mainstream ideas of how physics education is supposed to be arranged but, on the periphery, new ideas fight for entrance into the arena. Of course, the resistance to new ideas is a threat. The paradigms discussed in the thesis highlight how two streams are seen: – one that only takes its departure in the discipline and subject-matter content (of physics in this case), and one that only takes its departure in individual learning and individual choices, and in ideas of what and how to learn. I advocate a middle way whereby physics education keeps its knowledge-based focus on models and laws, but also opens up for student intervention into the physics courses by activities grounded in student questions and everyday experiences, and also gives more course time for discussions and communications around a more refined course content. A pragmatic solution to this is to keep conventional teaching methods but includes small-group work based on cooperative learning for up to 30 percent of the course time as a target for effective education (not yet proven).

My research started with the investigation of small-group work with miniprojects and context rich problems in physics. The contextual aspect was, first of all, seen as the environment where the physics problem was introduced, and particular effort was put into the circumstances whereby physics was adapted to everyday life situations relevant to the student. This made me focus on the conditional aspects of the small-group work; – how the tasks and the group situations were for the students that initiated the thinking of group ownership, later called SOL-g. However, the group discussions indicated that the context for the students started in their own experiences, which were highly individual and somewhat distant in time; a circumstance relevant for ideas referring to individual ownership, later called SOL-i.

Ownership is originally used to point out the relevance of increased opportunities for student activities and student autonomy in education and has been discussed since Moore (1973) advocated for learner autonomy as being important for adult learning. Ownership, as discussed in language learning, is a vague concept that hardly ever is sharply defined, but descriptions show how ownership is related to student influence on the management of the learning situation. Physics education has been seen as an authoritarian and closed community where teaching according to the old transfer model is too widespread. When the cognitive
sciences reported about the students’ shortcomings in physics understanding of basic concepts, initiatives from the physics community, itself, suggested new teaching approaches. Cooperative learning strategies, with increased student activity and opportunities for group discussions, was in line with this development. The small-group work, itself, became a guarantee for student activity and for opportunities to learn together with others. In this case, the small-group work is not important, as such; ownership has an individual character.

Milner-Bolotin defined ownership in physics education in a problem-based learning environment with small group-work, as the intersection between taking responsibility, finding a personal value, and feeling in control, and measured the individual status of ownership with a questionnaire. This is a very nice and fruitful definition that is, however, does not take into account how the group itself has impact on the individual. I perceived a limitation here. Milner-bolotin mentions this herself:

*In addition, group ownership and personal ownership may differ* (Milner-Bolotin, 2001, p.45).

When students work in small-groups they are in a situation where the group also has an influence on their individual opportunities to learn and to handle the management of the task or problem-solving. The situation in the group is the first place where the opportunities for ownership of learning are grounded; also for the individual. The group, as such, is responsible for the task management and for delivery of results that, in itself, sets limitations and opportunities for the individual learning process. This two-stage process is not dealt with in Milner-Bolotins work. We argue that SOL is a framework that also is useful to see ownership in the classroom more directly.

Savery advocated for fostering ownership of learning in a problem-based learning environment with a very broad description of “the environment of ownership”. With regard to his thesis, I also found a need to sharpen the concept of ownership of learning in order for it to be useful as a scientific tool.

In the thesis, I wanted to figure out how the individual in the group has ownership, and how the group situation, in itself, influences the ownership of learning. Small-group work induces a discussion of ownership of learning in two dimensions: on group–level, with realised opportunities for learning and management of the task, as well as on an individual level,- more in connection with the intellectual activity. It does not matter if the student group is in charge of the task management, if the student does not increase the opportunities to learn individually.
I regard communication with others to be a necessity for a learning process to start. Just arranging conditions for students to do group work does not give them ownership of their learning. We have discovered “exploratory talks” in the transcripts from small-group work in miniprojects and also in small-group work with context rich problems. The occurrence of exploratory talks, in agreement with Barnes, happen when peers trust each others and feel free to share ideas and experiences with each other.

_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._ (Barnes, 1973).

Even if Barnes originally found exploratory talks investigating children in the ages of 10 -11, we find the same pattern in our studies conducted in upper secondary school, teacher education and university. When students use exploratory talk, they are confident in their group and take the risk to open up in spontaneous discussions. This is an indicator for group ownership.

When we found the significant individual utilisation of own experiences or anomalies of understanding to start from in the problem solving of context rich problems or group investigations with miniprojects, I began to search for ways in which to describe this process in time, where old experiences, after reflective thinking, give new insights to a phenomenon. The old mimesis concept became relevant, and Ricoeur’s interpretation of the stages: _prefiguration, configuration, and refiguration_, was taken to categorise this process in time in three stages. The process is, perhaps, continuous although we tried to divide the students’ ideas coming back into these three stages several times. One can of course not see this process, but I use it as a metaphor to name the process indicators for SOL-i. When the student express own questions and comes back to these questions in different ways, by actions or talk actions, is it possible to categorise individual ownership.

Ownership of learning, together with the concepts, experience and mimesis, is an example of dynamic concepts that have a starting point, content, and direction. In accordance with the reasoning to how Jay (2005) and Dewey (1997) describe experience, ownership of learning gravitates towards a realisation of student influence when you start to use it as reflective tool.
SOL; as a scientific tool, can be used to analyse conditions for student influence and to study the beginning of individual learning processes. If SOL is realised in the classroom, it has been gravitating towards the realisation of a moment of “lived” student influence on both the learning environment and on the individual learning process. The student is dependent on the learning environment constituted by the small-group work, but the student also contributes to build this environment together with his peers and together with the teacher. By the choice of the task, the control of the execution of the task, and the responsibility of the presentation, the student influences the environment itself and the environment for the others. Consequently, one effect of SOL-g is that students really have an influence on the education that they are part of. This might have an effect on the individual student’s motivation and interest for physics as a subject. Our positive student evaluations from teaching sequences with miniprojects and context-rich problems give some evidence of this (Jonsson, Gustavsson & Enghag, 2006).

The individual ownership depends on how the group and the teacher have constituted the learning environment, but if this is positive for the specific student, the opportunities for learning are high. By SOL-i, the student can then develop his/her understanding of the circumstances that make the task of interest in the first place, and why it is relevant to him/herself and own pre-knowledge or experience. This increases the opportunity for increased physics understanding as conceptual change, or developing holistic or contextual understanding. In our studies, we have found that within all groups with high group ownership, all students do not have individual ownership. This observation can be interpreted partly because the instructional settings with miniprojects and context rich problems both have constraints; the small-groups have not been put together optimally, and the opportunities for SOL is not optimal. Perhaps some of the groups could have been chosen differently, with better output from more students but, on the other hand, this might not have been so easy to optimise; there are always moments for each of us when we do not feel at top level. An effect of SOL-g is still that we find ourselves in Vygotsky’s “ZPD”, or as Mercer puts it; we create an “intermental development zone”. (Mercer, 2000, p. 140). As a result, we may learn from others who are also in the situation whereby we are the one that gives feedback to the own questions of others and are arguing and discussing the questions that others have. I do find it of importance to point out this clear picture of only one or two students taking individual ownership of their learning in a group of three or four students. Thus, high ownership promotes motivation, knowledge-building, and personal growth.
This theory generating study, with multiple case studies, has resulted in a theoretical framework for analysing student ownership of learning during cooperative group activities in physics. Student influence in the classroom regarding learning physics activities resulted in a two dimensional model whereby the student performance of a task was under scrutiny in the dimension SOL-g, and the individual student development of new insight based on own everyday experiences or anomalies of understanding phenomena related to physics, was under scrutiny in the other dimension; SOL-i. SOL-g is based on the students’ realised opportunities for choice, control, and exploratory communication during the beginning, performance, and presentation of a teacher-generated task. SOL-i is based on individual student opportunity to develop own new insights in a mimesis process from own questions/ideas grounded in own experiences. SOL is a theoretical concept that produces, advocates, and elucidates student influence.

Analysing the group discussions from “the ownership perspective” gave findings for group student ownership of learning; The students could choose and control the task itself, the execution of the task, and the presentation, and also contributed to the development of the learning environment. It is clear that they participated creatively in the shaping of their own education; they had student influence in the classroom. They also broadened themselves with respect to holistic understanding as they chose phenomena related to environmental issues (The Solar Wind, The Thunder) or technical applications (The Electric Circuits, The Electric Motor, The Transformer, The Handbook to Safe Electricity). However, at the same time, they avoided all MPs that demanded mathematical problem-solving (See Enghag, 2004). All of the miniprojects groups had high SOL-g. The SOL-g was more limited within the cases with CRP, the context rich problems. Here, the opportunity to choose between different CRPs increased the SOL-g considerably. The presentation of the CRPs was not detailed enough, thus, it had to be improved with much more feedback from the teacher. All groups that were studied fulfilled their assessment with respect to solving and presenting the CRPs and MPs to the teachers. One consequence, related to the high SOL-g in the cooperative learning situation, was the high motivation that all the students showed. The commitment was remarkably high; seen in the transcript with almost no talk related to issues beyond the task. It is reported from literature (Johnson & Johnson, 1994; Deci, Vallerand & Ryan, 1991) that high motivation, high self esteem, and good effects on human behaviour is connected to different kind of teaching situations with cooperative groups. In this study, evidence for high motivation is seen, but the students are not asked about their personal feelings of the learning situation. (13 interviews were carried out but have not yet been
analysed). However, as we also investigated the individual student ownership of learning, SOL-i, it was striking that only one or two students in every group manifested own student generated questions that they worked on. It was also striking how the peer students, actively and positively, acted towards the generated questions of these peers. They supported the performance experimentally and provided a helping and supporting attitude to find answers to the issue at hand, even if the student generated question was quite peripheral to the task in their MP or CRP.

Further analyses of the SOL-i, the individual ownership of learning, showed that, concerning dimensions of mimesis, there was only one or two students in a group that developed learning as new insight into a phenomenon that they had previously encountered some problem with, and from experience had an interest in, or a problem with. This appeared independent of whether they worked with MPs or CRPs. Obviously, all students had some training in the performance of physics related tasks, project work, or problem-solving, but it did not necessarily follow that learning physics, seen as new insight in experience-related issues, was implicit for all students. On the other hand, at least one in every group was impressive.

This brings us to the opportunities for this to happen. In this study, the tendency was that the more familiar the groups were, for example, if they had worked together before or were “at the same level”, the easier it was for them to enter into exploratory talks about own personal questions. This observation is also strengthened by other researchers (such as Edwards, 2005), advocating for the opportunity for small-group work to continue with the same groups for a longer period to increase this positive effect. On the other hand, the Minnesota University Cooperative Research Group recommends groups of three with different abilities and social background. It is possible that these contradictory observations are due to the perspective of the individual, or the class as a whole. One of our groups showed one student who did not communicate at all with the other students; the teacher did not notice.

Student influence is increased if student opportunity for choice, control, and communication in exploratory talks is allowed. The implications are high motivation and enhanced social qualities. The opportunity for enhanced individual ownership of learning is seen for some students in each group during these cooperative learning activities, and the opportunity for all students to practice inter-thinking (Mercer, 2000) or for new experiences to create staring points for new mimesis processes, is obvious.
10 Implications for research

A further investigation that I will continue with, is to analyse the 13 interviews with aeronautical engineering students in a semi-structured interview situation in 2005. The interviews were gathered for the purpose of finding out about the students’ understanding of physics education, of context rich problems, group discussions, and of the opportunity to deal with own experiences. Other new research questions that could be grounded in the SOL framework include the following:

1) Further investigations about how to promote additional students with high SOL-i during group work:
   What circumstances facilitate small-group work where more than one or two persons have SOL-i? How do teachers observe student related questions, and how is feedback constructed based on student generated questions?

2) Student ownership of learning from a teacher perspective: – a challenge and an opportunity for the teacher ownership as well:
   Could a team of teachers associated with small-group work in physics create a better learning situation also for teachers? What make teachers feel ownership of their learning?

3) Is e-learning a way to promote SOL:
   The specific impact from ICT on SOL, is a research question I really want to deal with, as ICT started the process towards increased awareness of student ownership and its implication in life long learning.
Epilogue

I now return to the question: “Why do students not choose science?” and to Sjøberg’s list of reasons why students turn away from science. Included in the physics-culture core or nucleus, From the list of arguments that are held as reasons, the following could be included in the physics-culture core or nucleus:

1) scientific knowledge is by its nature abstract and theoretical
2) the problematic values and ethos of science
3) the scientist as a neutral defender of objectivity and truth
4) the image and ambitions of modern biotechnology - scientists who are 'tampering with nature' or 'playing God'.

Other issues are peripheral to the physics-culture:

1) anti- and quasi-scientific trends and 'alternatives' such as ‘new age’
2) postmodernist attacks on science and technology.

Teaching physics as physics-culture also implicates the discussion of these nucleus/core and peripheral issues within physics as a subject, in order to make it interesting for different student groups. This is, of course, a challenge to physics teachers who work, and have been working for a long time, in the body of knowledge or normal discipline area, as it calls for interdisciplinary knowledge and courage. Students ask their teachers how one can believe in the Big Bang (core) and if there are healing effects from stones (periphery). These questions cannot be dismissed with regard to physics as authoritarian knowledge but have to be talked through seriously.

However, there are still reasons on the list not yet covered by the physics-culture model, and they all touch upon identity:

1) a stereotypical image of scientists and engineers, 2) the earlier image of the scientist as a dissident or rebel has been replaced with a less exotic image of a worker loyally serving those in power and authority, 3) A white-coated, hardworking, and not very well paid, scientist in a laboratory is not a role model for many young people today and 4) A communication gap between scientists and the 'public'.

When you learn you change yourself, and when you choose to study physics you risk being influenced by the teachers and the physicist in the way in which they make an impression of you. You participate in a culture, and you might be a member in a community of practitioners:
"Legitimate peripheral participation" provides a way to speak about the relations between newcomers and old-timers, and about activities, identities, artefacts, and communities of knowledge and practice. A person’s intentions to learn are engaged and the meaning of learning is configured through the process of becoming a full participant in a socio-cultural practice. This social process, includes, indeed it subsumes, the learning of knowledgeable skills.” (Lave and Wenger, 1991, p. 29)

As mentioned earlier, I advocate for a middle-way in the struggle between the two educational paradigms Lemke refers to this as Curriculum versus Information Access (Lemke, 1994), and Sfard calls it the acquisition versus the participation metaphors (Sfard, 1997). The joint problem-solving is carried out by the access to Internet and the computer mediated communication part of the new paradigm. The personal guidance that a tutor can offer, as organiser and trouble-shooter and by scaffolding, has, however, too much to offer the student for the curriculum paradigm to be over-played. The main reason why I believe in a middle-way between the two paradigms is the importance of the teacher in education. The teacher is the guarantee for a balanced and trustful environment and has the responsibility for creating a friendly and positive atmosphere in the classroom. The teacher can also invite the student to dialogic or physics-culture talk that include nucleus, normal science (body area) and peripheral knowledge.

However, in order to succeed with this endeavour, student ownership of learning has to be considered. No “socialisation into physics thinking” is compatible with education in the physics-culture. The community of practitioners, within the physics-culture, are organisers of a learning environment that gives opportunity for student ownership of learning. By providing tasks from different parts of the physics-culture, the teacher becomes involved with the student-generated questions that arise; qualified teachers must take this challenge and be rewarded by increased awareness of the complexity of physics-culture.
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