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TWO DIMENSIONS OF STUDENT OWNERSHIP OF LEARNING DURING SMALL-GROUP WORK IN PHYSICS

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ABSTRACT. The theoretical framework *student ownership of learning* is developed both theoretically and with qualitative research. The metaphor "ownership" is related to the process towards meaning making and understanding and is seen as relevant especially to improve physics instruction. The dimension *group ownership of learning* 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*, refers to an individual student's own question/idea that comes from own experiences, interests or anomalies of understanding; an idea/question that comes back several times and leads to new insights. From literature and from our own data, we have developed categories for group and individual student ownership of learning, which were iteratively sharpened in order to identify ownership in the two dimensions. As a consequence, we argue for use of the framework student ownership of learning as a way to identify an optimal level of ownership for better learning and higher motivation in physics teaching.

KEY WORDS: group work, miniprojects, physics teaching, student ownership of learning

Introduction

This paper is *part of a larger study* to analyse group work in physics instruction with miniprojects and context-rich problems. For the study, three areas of significance can be pointed out: First, a better understanding of the critical aspects of students influence to their own learning. Secondly, to support teachers with some insights into the design of learning tasks, which incorporate small-group work in physics. Third, the development of a methodology within which the empirical research will take place. 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, miniprojects and context-rich problems with group discussions. 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 on ownership of learning within a constructivist perspective (Dudley-Marling & Searle, 1995; Milner-Bolotin, 2001; Savery, 1996). The methods for analysing the group discussions are based on discursive moves (Barnes & Todd, 1977, 1995). From the transcript of a group discussion, an examination to identify the moves that make up the complex discussion is made. Initiating a discussion of a new question and qualifying another person's contribution or extending a previous contribution are examples of discursive moves.

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; she measured the individual status of ownership with a questionnaire. This is a very nice and fruitful definition, which we however like to sharpen. We saw a limitation here: when students work in small groups they are in a situation where the group itself also has influence on their individual opportunities to learn and to handle the management of the task or problem solving them. 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.

The part of the study reported in this paper investigates student ownership of learning (SOL) during group work in a physics course in electro-magnetism in physics teacher training. The students worked in groups for 20% of the time; the course included also ordinary laboratory activities, lectures and problem solving. The instructional design for the small-group work used in these case studies is called *miniprojects* (Enghag, 2004) or *group investigations* (Slavin, 1988). It is grounded in the basic principles of cooperative learning (Johnson & Johnson, 1991): positive interdependency "students sink or swim together", face-to-face oral interaction, individual accountability. Each student has to master the material and feedback and discussion of students' achievement is an integral part of ending the activity.

The analysis of ownership in miniprojects comes to categories, which were iteratively constructed with qualitative methods (Niedderer, 2001).

Theoretical Background

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). Only more recently, this concept was applied to science education research; in physics education at university level it was used by Milner-Bolotin (2001) and Enghag (2004). So, ownership theory has grown from teaching in informal settings into formal and from language teaching into science teaching.

Student ownership of learning focuses on the students' activities to influence the organisation, the content and the individual learning. Balancing the relationships of power and authority, creating spaces for everyone to contribute and to advocate students to be resources for one other (Rainer & Matthews, 2002) are the core of a framework to understand ownership. We see ownership of learning as a concept, which argues in similar directions as students' influence on learning. The interim report of the Swedish school committee (SOU, 1996) establishes three reasons why students should have influence on their learning:

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

Ownership refers to the importance and need for students to actually participate by discussions, choice, responsibility and decision taking; it stresses the real actions of choice and control by the learners. The social interaction in small-group work helps to negotiate meaning and develop understanding (Barnes & Todd, 1995); these are very important outcomes we expect especially from students developing ownership.

Importance of Ownership to Enhance Motivation and Learning within Physics Education

Today, when the number of students in physics education shows a worrying trend of decreasing (Benckert, 1997; Jenkins, 1994; Lindahl, 2003; OECD, 2005; Sjøberg, 1998) there is a reason to reflect on how to increase student motivation in physics. Other researchers think in the same direction, and find a need for increased student autonomy:

> Further support to this is lent by our work (Osborne & Collins, 2000) that found pupils desired more opportunities in science for practical work, extended investigations and opportunities for discussion – all of which provide an enhanced role for personal autonomy. (Osborne, 2003, p. 1074)

Student autonomy here is seen as a result of students developing ownership.

Kentish (1995, p. 25) found that ownership was critical for the success of an educational program, due to the fact that more students finished the program when ownership evolved. Greater student responsibility enhanced motivation of the students and was critical for deep learning. 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 maximized 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 than intrinsically motivated.

Rainer & Matthews (2002, p. 22) find that ownership describes the central and cohesive elements of knowledge construction by the way students when they are active learners are agents in their own learning and relate own experiences to new knowledge, making learning their own. When we study student ownership of learning, we study both the group situation in the classroom and how the individual knowledge construction and meaning making of the student take place.

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 aspect is the opportunity to choose a task regarding the level of difficulty and the 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 to their learning situation is to give several tasks with different levels of complexity to choose from. Another way is to give a more open-ended task and tasks more open to student contribution.

The Distinction Between Group and Individual Student Ownership of Learning

Ownership is mainly defined by actions of choice and control taken by the students during group work. This is called *student ownership of learning (SOL)*. Some of these actions are obviously more related to the group, e.g. to determine the common understanding of the task, to decide on how to organise the work or how to organise the presentation. Others are more related to one individual student, e.g. to have a special question or idea. So it seems natural to define student ownership of learning in two dimensions: as *group ownership of learning (SOL-g)* and as *individual student ownership of learning (SOL-i)*.

The question of student ownership of learning comes up or starts, in 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 that together can be considered as ownership. First is the power process: opportunity and responsibility to take decisions about the task itself and how it is going to be implemented and fulfilled. Second is the management process: how the task is practically implemented and the results presented. 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 underpins (1) how the task will be finally formulated in all details before work, how the management of the task is fulfilled and how the production of the result will be presented, but also (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 – students' actual influence on their physics learning. The underlying process has two inseparable aspects 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 instructional setting by the teacher. SOL-g describes what is realised by the group, and SOL-i refers to activities to bring up own ideas and difficulties, realised by the individual student.

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 if 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 have the students 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 to 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 a 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 students invent a task themselves, instead, is it more likely that the teacher proposes open-ended tasks including driving questions that trigger and draw out 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 for student-generated questions, is used by Crawford, Marx & 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.

Research Questions

The questions guiding us in our work have been to:

- Describe and clarify theoretically group and individual student ownership of learning during small-group work in physics, and develop categories for these two dimensions of ownership
- Analyse group and individual student ownership with categories in a case of group work within a miniproject and discuss the effects of ownership on the groups proceeding of the task
- How do the student-generated questions influence talk, learning and results during problem solving in small-group work in physics? Results to this question have been published elsewhere (Enghag & Niedderer, 2005; Enghag, 2004; Enghag, Gustafsson & Jonsson, 2007)

Developing our Theoretical Framework by Formulating Categories for Student Ownership of Learning (SOL)

Development of Categories for Group Ownership of Learning (SOL-g)

The general definition of ownership is actions of choice and control. One important aspect of SOL-g is the *ownership of the task*, when the students together with the teacher decide on the management of the task.

How much influence do the students actually realise in determining the task and its details? In our categories we look for students' actions, which show autonomy, control and choice. We analyse the students' actions in this directions at the start, during performance of the task and also during the presentation of the results. Savery and Duffy (1995) 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 of teaching that gives students ownership of the problem but dictates the process for working on that problem. We take this statement as one argument that supports the categories of SOL-g. The students chose tasks and group constitution (first category) but they also chose and control the management of the task by decisions of what activities that have to be executed to reach the results they search for. Group discussions are important to realise these events (second criteria). This finding is in line with the view of ownership as a process in time, and in our categories (see Table I), we look for student actions to control and make choices, at the start, during performance of the task and also during the presentation of the results. Indicators are seen as specific examples to help for better categorisation.

Development of Categories for Individual Student Ownership of Learning (SOL-i)

The characterisation of *individual student ownership of learning (SOL-i)* starts with the general definition of ownership: actions of choice and control taken by the individual student during group work. Another starting point for our iteratively developed category is the observation that the autonomous learner works with high intensity on his or her own ideas and is persistent to these ideas. It is important for the learning process that the learner creates his or her own problems and develops his or her 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, 1995, p. 31)

We find that to have an own question or idea and take the opportunity to work on it and come back to it with new actions or results, is an important way to make an individual choice and have control of a part of the content. So, we see this as a main category for individual student ownership of learning: to come up with an own question or idea and develop this idea throughout a major part of the group work.

TABLE I

Categories for group ownership of learning (SOL-g) with descriptions and indicators

Categories for SOL-g	At the start	Performance	Presentation of results
Description	The group takes actions of choice and control with respect to the task	The group takes actions of choice and control with respect to organisation and content of work	The group takes actions of choice and control with respect to formulation or presentation of results
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

Also 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. It indicates that a student has his or her own ideas about an interesting topic.

As we find the individual student ownership of learning (SOL-i) to be a process in time, we found a striking resemblance to the *mimesis* concepts developed by Ricoeur from Aristotle's *Poetics* (Ricoeur, 1984). 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, as by looking at a painting or watching a theatre play or talking to someone, can reach another view of the phenomenon. Finally, a new insight can come out of the process. The phases in this mimesis process are named prefiguration, configuration and refiguration.

So there is only one category SOL-i, and we look for a specific idea or question of one individual student during the group work. In order to follow if this own question/idea comes up again and if the student expresses new insights related to this same idea, we call this as a first process criterion *prefiguration*, i.e. an own question/idea is expressed. The second we call *configuration*, which means that the same question recurs, and finally the third is *refiguration*, when new insights are expressed, related to the same question or idea. If all these process criteria are seen we interpret this as *individual ownership of learning is created*. It means that a student has developed ownership of one aspect or question or idea, which is "his or her own" in the sense that he/she has developed a special motivation to find a solution or answer for this aspect. An overview of the developed category and its process criteria are shown in Table II.

In some cases we find that if a student develops this kind of ownership, he or she also begins to develop understanding and makes a transition from an everyday life view towards physics understanding (Enghag et al. 2007; Enghag & Niedderer, 2005).

The Category for Individual Student Ownership of Learning (SOL-i)

SOL-i is a construct that shows if a student takes the opportunity to work on an own question/idea. It is especially important if he/she is free to work on the obstacles he/she might experience before he/she has opportunities to develop the understanding further. We call this "SOL-i" only if the process criteria prefiguration *and* configuration *and* refiguration are all positive with the same question/idea.

TABLE II

The category for individual student ownership of learning (SOL-i) and the corresponding process criteria prefiguration, configuration and refiguration

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

The individual student ownership of learning (SOL-i) is confirmed if a student makes observable actions of choice and control in process described by:

- Expressing an "own" question/idea of special importance to him or her (prefiguration)
- Showing commitment to this question/idea by coming back to it during group work in significant ways (configuration)
- Comes back to this question/idea with sign of development of the question/idea towards new insights (refiguration)

Method

Participants and Choice of Miniprojects

The investigation was carried out with 14 students (prospective teachers) in physics. At the end of their second physics course, electrodynamics, with a total of eight weeks, they worked for 2 weeks on miniprojects. The Transformer Group with four male students here called Mattias, Kenneth, Jonas and Markus, made a final choice of the miniproject "Illustrate the transformer and transform current and voltage". In total, five groups with different miniprojects worked together in the laboratory.

Data Collection

At the beginning of the study, the 14 students were divided into two groups that were audio recorded when they discussed suitable miniprojects, at first their own ideas, but later on they had a choice among 20 miniprojects on a list prepared by the teacher. At this time, the student Mattias was in the first group and the three others in the second group. After this first discussion they made written proposals for the miniproject they wanted to investigate, and groups were constituted based on these choices. During the lab days, they recorded themselves for 4×45 min, and were allowed to switch off the tape recorder whenever they wanted. The final presentation was video recorded. The recordings were transcribed.

Developing Categories for Student Ownership of Learning

The categories were iteratively constructed with qualitative methods (Niedderer 2001), combining theoretical development from literature and experiences from qualitative steps of analysis. The categories were at last revised by interrater agreement calculations.

Interrater Reliability (IR)

Interrater reliability refers to the level of agreement between two independent raters on a particular instrument on a particular time. When interrater reliability is used as a consensus estimate a typical guideline found in literature is that it should be 70% or higher (Stemler, 2004; Niedderer, Buty, Haller, Hucke, Sander, Fisher, von Aufschnaiter et al. 2002). In this investigation *interrater agreement* is used with the researcher as one of the raters. This was done in an iterative process in order to improve the description of the categories and the indicators.

Results

Description of Instructional Settings

Conditions at Start. At the start, the students discussed in groups a list of 20 proposed miniprojects, including number one, a totally free choice. They finally choose individually those miniprojects with a clear holistic approach and avoided those with a mathematical problem-solving approach, which were proposed in the list as well. The 14 students constituted five groups based on their choices of miniproject:

- "The Thunders-phenomena in the electric field around the Planet Earth." (two students)
- "Illustrate the transformer and transform voltage and current". (four students)
- "Handbook for teachers-safety with electricity"(three students)
- "The Earth's magnetic field- The Sun Wind-van Allen Belts" (two students)
- "Make an electric motor and explain how it works."(three students)

Management Responsibility During Performance. The groups differed in the way they chose to perform the miniprojects, some made a literature review whilst others performed experiments. All were focusing on some issues related to their everyday life. All miniproject groups did take responsibility for the management by control and choice of the task performance, but came to proceed very differently in their activities.

The Way to Present the Results. The teacher had made clear that a final presentation had to be executed at a given time and day. All groups reported their results in front of the class during 20 min, with a 10–20 min of discussion, and a written report or a PowerPoint presentation had to be produced for assessment for the task.

The Transformer Group's Group Ownership of Learning (SOL-g)

At the Start. All members of this group had given a written proposal to choose this miniproject. Those students with the same choice then constituted the groups. This gives the group SOL-g regarding the first category as both criteria are fulfilled. Their proposal texts:

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 out in reality. Could be fruitful to know how a transformer works in a transformer station for example, and how a transformer station works itself. How current reach the households.

Jonas: This subject seems to be the most interesting and that makes it more fun to work with.

Mattias: We are surrounded by transformers. They stand for an increasing part of current consumption. I should like to have impact in this in aspects of the environment, and how are allergic persons affected?

During Performance. The group showed SOL-g by deciding to start with experimental work in the laboratory and with intense group discussions. They made the design of their study, and they used frequently group talk, e.g. in the form of exploratory talks, for increased physics understanding and meaning making. Together, as examples, the group decided the following group activities: exploratory talk to explain how a transformer works, searching the Web for "transformer", measurements of current and voltage in an school transformer, and many other activities.

The Presentation of the Results. The presentation was decided by the teacher to be a 10–20 min 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 a transformer work?
- Practical use of transformers
- The group's reflective thinking

The group presented their results orally, based on PowerPoint presentations. Mattias was 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 their theory by experiments that transformed voltage in 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 audience was good with questions and discussions. Mattias' and Kenneth' parts of the presentation were clearly related to their individual own questions (see below about SOL-i results).

So to summarise: group ownership of learning (SOL-g) was high with respect to choice of miniprojects, control of task performance and of presentation. The final presentations showed how the group from an open-ended task had created a presentation of a physics-related topic and was able to defend this in front of the teacher and the other groups. The way the group came to this product could be described by several decisions the group took on their way (SOL-g) and also by how individual students' own questions had impacted on this product and helped to initiate a learning process (SOL-i, see below).

Individual Student Ownership of Learning (SOL-i)

The group discussions showed how two students inspired the group to discuss and deal with their own questions. We study those two students actions in more detail in this section to show in two cases what we see as individual student ownership of learning.

Case Study 1: Mattias' Individual Ownership of Learning (SOL-i)

Prefiguration. Mattias expresses already in the first group discussion about possible ideas for miniprojects his own question: His young son had an accident with a small transformer at home. Mattias is surprised that his son could get hurt by a transformer and is interested to learn more about how the transformer works. The difficulty to understand the accident he observed is expressed in the excerpt where he also refers to the experience with his son again. He shows interest. All this was coded with "prefiguration (Pre)".

Mattias: I was thinking on this... and than I found something I did not understand.

Well, the transformer.... it started with my son, he got hurt because of a torn transformer...and nowadays we have those small transformers all over the place...inside every electric thing...when it is not 230 V there is a transformer somewhere-

I think it could be fun to think of it....

Later on he discovers a miniproject connected with transformers in the list of suggestions from the teacher, and gets excited. He immediately wants it. The two raters indicated both the category “prefiguration (Pre)”, so both saw the same question/idea coming again.

Mattias: And now 14 (miniproject “transformer” in the list)-by a pure coincidence- I...this one I can think of...the transformer

Configuration. During the first laboratory session after their theoretical preparation, Jonas and Kenneth start to experiment with transformers available in the lab. Markus and Mattias discuss more theoretically how the transformer can be explained with concepts of physics. Mattias tries to contribute with an unexpected explanation for the result that they found less than the expected 20 V. He is working on his previous own question again. His question has developed into a hypothesis about energy losses in the transformer, causing the transformer to get hot. This shows how the question has recurred and also started to be developed towards a more physics reasoning. This we see as a sign of configuration (Con):

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

In the transcript 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 how the transformation can be explained. Mattias talks about what he has read in the literature and he also refers to his son’s textbook from school that has nice an easy explanations about how the transformer works and how voltage transformation is dependent on the number of turns of the coils. This information shows that the group is very committed to this task in all its parts, not only in the aspects of Mattias’ question. So, we see group and individual student ownership of learning both effective in this group work.

Later on, Mattias in discussions with the others formulates his hypothesis that there are energy losses inside the transformer that cause the transformer to get hot. This means another move from everyday understanding to a more physics-related understanding.

Mattias likes to measure these losses, and the group decides to buy a new instrument that can measure energy, power and even energy expenses. They order this instrument from the teacher who arranges it on the same day. This special action is also a sign of configuration (Con). When Jonas and Mattias begin the measurements, Jonas is the one who understands the instrument:

Mattias: Haha haha. It looks as if you can set it to costs directly!
Jonas: Energy price-we don't have one-what is the energy price-I don't know that...we don't have one...
Mattias: No, but the point is to try to find.... why has it stopped here?
Jonas: But you have turned off the lamp, haven't you?"
Mattias: Is it that miserable? Is it that miserable? Has it to be that miserable?

Mattias' contributions are hard to understand at a first glance. But if we look to his contribution, 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. In this view, his repeated statements mean that he has expected much higher measurements of power input into the transformer. So, we see clear cases of configuration (Con) of his first question here. At first his friends do not grasp his ideas. This is also strong evidence that he really has ownership to this question.

Jonas: But it is off, isn't it? You have turned the lamp off! The energy will only go when the lamp is on, you see.
Mattias: Yes, but my point was to show that there are energy losses even when the lamp is off...

We leave the transcript here for a moment. Mattias develops the issue further when he suggests taking measurements for a longer time, hoping for better results about energy losses, again showing commitment and actions along with his own question (SOL-i). And Kenneth finally confirms that he understood Mattias' question. But while the other group members take it as good result to find no energy losses, Mattias insists on energy losses in the transformer even if the lamp connected to the secondary side is off.

Mattias finally takes the instrument home with him, also a sign of configuration by this special action, and can detect energy losses in this special transformer his son got hurt from, but in no other transformer in his home, a circumstance he later reports in his presentation.

Refiguration. During the presentation, Kenneth and Jonas make practical demonstrations of how to transform voltage and current. After them, Markus gives an introduction to the transformer in society, and also to the theoretical expressions for transforming voltage and current. Mattias finally continues with an explanation of the group's reflections on energy losses and measurements from their investigation. In the transcript from the presentation, 24 of 33 statements of Mattias are marked as refiguration of both raters, by itself a sign of how committed Mattias has been to find a solution to his own question. These findings give strong evidence for his student ownership of learning (SOL-i) in this situation.

Mattias shows both reflections and transition to new insights in physics during his presentation. He explains how the group has found, by practical experiments, that transformers have energy losses, as they do not transform 100%, which is assumed by theory. He also tells the others that he was thinking of this because his son had an experience with a hot transformer at home earlier. These lines were seen as "refiguration" (Re) with indicators "reflection" and/or "transition to physics":

Mattias: Than we go to the reflections of the group. Does the transformer change voltage and current without losses? Theory said it should. (Points at Markus formula on the white-board.) In the practical experiments we have seen that this is not the whole truth. There are losses somewhere. These were also some of my thoughts, when I had found at home, in the beginning, that transformers get warm. 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)", Mattias talks physics and explains 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 seen as "refiguration" with the special indicator "transition to physics".

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). It depends on different factors. Partly, it is the coils itself, as a coil contains wire with some resistance. But you remember, we have also the iron core that gives a resistance in the iron if the current changes, and the magnetic field is induced in the core. Also, eddy currents that are formed when the iron is heated. Then hysteresis exists; it is when iron orientates itself in the same direction...I think this is called idle running current...I am not totally sure about this....But it is a cost to keep the transformer running One sees clearly that it is 6 W...

Mattias has been persistent to his question about why a transformer can be hot, which has recurred several times, was reformulated in the configuration phase (by special actions) into a search for energy losses. In this stage he now refigurates the question, by reflective thoughts of the reason and effect of what he has found. This is high individual ownership of learning (SOL-i), as all three stages pre-, con- and refiguration are gone through.

Mattias 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 presentation he presented new types of materials on the market that decrease the problem. He discussed if energy losses is an economic problem for a family. He has taken his own question in a mimesis process towards new insights, and by that he has both individual student ownership of learning (SOL-i) and good learning progress in physics.

Interrater Agreement with the Mattias Case. The categories for individual ownership of learning were constituted by an iterative process as one part of the interpretive analysis of the transcripts. Revisions of the categories were made to sharpen the categories and make them feasible to detect SOL-i. The first draft of the "final" categories was coded by two raters. Difficulties to interpret the configuration phase were observed.

After further revision of the categories a second coding process was done, which resulted in increased agreement with statements showing individual student ownership of learning of Mattias. The overall interrater agreement of all statements in all three phases (pre, con and re) concerning the "own question" was high, 82% (altogether 55 statements). We found it enough to make interrater agreement calculations for this main category only, as the process criteria are not seen as categories themselves, but more as help for categorising SOL-i. The indicators for the process criterion configuration was however not yet defined clear enough to be understood by the second rater who missed some of statements the first rater coded as configuration. This interpretation was discussed before the next case was coded.

Case Study 2: Kenneth's Individual Ownership of Learning (SOL-i)

Prefiguration. Kenneth shows individual ownership of his learning too. He expresses interest in the transformer during the group talks before the final choice of miniproject, and we interpret this as prefiguration (Pre) of his own idea, which we reformulate as "how to explain real transformers from the real world". The first statement showing this idea-as some kind of joke, but later becoming very serious-was marked by both raters as prefiguration (Pre), which means at the same time SOL-i:

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 brings a private transformer into the lab session to see how it works in reality. His initiative to bring a commercial transformer with him is grounded in his experience of his father's transformers at work. His special action to bring the transformer to school is a way to say that the transformer is a real transformer from the real world. This special action already was coded as configuration (Con), using the second indicator. As he obtained the transformer from his father, this gives Kenneth additional ownership. His own idea at start was to bring a real transformer station into the classroom and to explain how electricity was distributed in society. This idea now grows into a need of a more practical understanding of how the transformer works. Kenneth finds that there are lots of technical details to be seen in a transformer of the real world, and he is interested to understand this commercial transformer, but he cannot see the coils in this real world transformer. He wants to apply his physics knowledge to this part of the real world: there should be two coils.

Kenneth: Well, I bring this one for you.... if someone likes to investigate it also next year

Teacher: Yes, that's nice...

Kenneth: I have got it from my dad. He works in a car firm, you know, and they expose car stereo apparatus. Then they take 230 V and make it 12 V for the car stereos.

Teacher: Yes, ok.
Kenneth: But it is not only the coils and magnets it is a thousands of other things too...
Teacher: Well yes, this is a rectifier ...mm...that is interesting of course...
Kenneth: Yes. Unfortunately you can't see the coils.

Later on he returns to his interest in other technical applications of the transformer in the real world: The real transformers are transforming 400 kV to 380 V.

Kenneth: Isn't that exactly what happens in a real transformer out there?
Kenneth: Because these lines are for 400 kV aren't they?
Mattias: Yes
Kenneth: And in some way is 380 V distributed out 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 show experiments during the presentation, they transform voltage and current. But Kenneth also returns to his own question –the use of real transformers. He tells the others about the commercial transformer he brought to school. He explains his new insights of how physics can explain how electricity in society works in a confident way, and he finds a reason to the question why we transform electricity when there are large energy losses. He understands the use and the function of the transformer. He has had ownership of his learning by his opportunity to let physics understanding grow by the development of his own question at start.

Jonas: When and why do we use transformers? We use them everywhere. For lamps and...
Kenneth: (interrupts Jonas) We use them to get less transport losses in our lines through the country.
Jonas: And we use them at home too.
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 bee 230 V.

Interrater Agreement with the Kenneth Case. Both raters recognised the same question/idea with 93% agreement (28 statements in total) thus determining individual student ownership of learning (SOL-i) with high agreement.

Discussion

We find it important that physics teachers develop their instructional design in a way that promotes student influence. Young people struggle with tough responsibilities in their everyday life, and the way they are treated at school is often underestimating their abilities.

> ...the structures of secondary schooling offer, on the whole, less responsibility and autonomy than many young people are accustomed to in their life outside school, and less opportunity for learning-related tensions to be opened up and explored. (Rudduck, Chaplain & Wallace, 1996)

Different instructional designs give different conditions for ownership to grow. The theoretical framework for student ownership of learning (SOL) gives teachers and researchers a tool to control how supportive to autonomous learning the educational situation actually is. The *group ownership of learning (SOL-g)* allows analysing ownership at start, during execution, and at presentation of the final product. Within the group, the other dimension of ownership, the *individual student ownership of learning (SOL-i)* allows to analyse how much the individual student is actually following own ideas. Every student has questions, experiences and anomalies of understanding that have to be worked out before new learning can occur during fulfilment of a task.

This case study describes the ownership during a sequence within a miniproject as part of a traditional physics course. By using the defined categories, the group ownership in this case could be shown to be high. It was high with respect to how the group chose the task, how the group constituted itself and how they controlled management and content of the performance process. Two persons of four in the group showed high individual ownership and their questions determined to some extent the direction of the group work. The other two students were motivated too, but did not contribute with pertinent own questions. In fact they were supportive of the autonomy of their peers instead, with commitment to the group's final presentation of results.

We argue that awareness of group and individual ownership promotes competence development for both teachers and students. There is evidence in our data, especially from the refiguration phase, that there are positive effects of SOL-i on learning. The individual expertise and experiences of learners are more than teacher's demands the driving force of the learning process, as participants become investigators collaborating in search for understanding. However it is important to consider also the restrictions of both group and individual ownership. In this paper, we consider ownership in small-group work that is placed at the end of a traditional physics course, which includes lectures *and* traditional elaborative work as well. The question of the optimal level or amount of ownership has to be discussed. When Mortimer and Scott discuss *staging the teaching and learning performance* (Mortimer & Scott, 2003), they give a frame to locate student ownership of learning within 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. We also see this as the responsibility for the teacher, and we agree with their view of ”*handing over responsibility to the student*”, that follows from Vygotskys' learning theory to go from *assisted* to *unassisted* performance. The contribution with two dimensions of student ownership of learning in group tasks is to increase awareness of how ownership is useful as a theoretical framework discussing students' actual influence to their own learning and how group work both gives opportunities and constraints in this endeavour.

When the student as an autonomous learner has ownership, she/he is free to start from the own experiences and personal needs to proceed towards learning. Mattias likes to understand why the transformer gets hot, and Kenneth how the distribution of electricity is organised in Sweden and where the transformer comes in. These questions have to be addressed and then further information about physics concerning the transformer becomes relevant.

Conclusions

This paper is one part of a study of student influence in the classroom regarding learning physics activities. We have developed a model of student ownership of learning as defined by students' actions of choice and control. This model describes ownership of learning in two dimensions: on group level we have the concept SOL-g, based on the group's actions of choice and control of content and management during group work; on an individual level, we have the concept SOL-i, based on the individual students actions during group work to develop own questions/ideas grounded in own experiences, and develop own new insights in a mimesis process related to this question/idea. SOL is a theoretical framework that produces, advocates and elucidates student influence. There is evidence that with more student ownership of learning physics instruction can become more effective, both with respect to motivation and learning.

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REFERENCES

Barnes, D. & Todd, F. (1977). *Communication and learning in small groups*. London: Routledge & Kegan Paul.

Barnes, D. & Todd, F. (1995). *Communication and learning revisited: making meaning through talk*. Portsmouth, NH: Boynton/Cook Publishing.

Benckert, S. (1997). *Är fysiken könlös? Reflexioner kring ett universitetsämne*. Stockholm: Symposion (in Swedish).

Crawford, B., Marx, R. & Krajcik, J. (1999). Developing collaboration in a middle school project-based science classroom. *Sci Educ 83*(6), 701–723.

Deci, E.L., Vallerand, R.J. Ryan, R.M. (1991). Motivation and education: the self-determination perspective. *Educ Psychol 26*(3&4), 325–346.

Dudley-Marling, C. & Searle, D. (1995). *Who owns learning? Questions of autonomy, choice, and control*. Portsmouth, NH: Heinemann Educational Books.

Enghag, M. (2004). *Miniprojects and context rich problems : case studies with qualitative analysis and motivation, learner ownership and competence in small group work in physics*. Swedish national graduate school in science and technology. Department of Thematic Studies, Linköping Univiversity, Norrköping, and Department of Mathematics and Physics, Mälardalen University, Västerås. Licentiate thesis.

Enghag, M. & Niedderer, H. (2005). Physics learning with exploratory talks during a miniproject-a case study of four girls working with electric circuits. *J Baltic Sci Educ 1*(7):5–11.

Enghag, M., Gustafsson, P. & Jonsson, G. (2007). From everyday life experiences to physics understanding occurring in small group work with context rich problems during introductory physics work at university. *Published on Line in Reseach in Science Education*. Available at: http://springerlink.metapress.com/content/1573–1898/?k=Enghag.

Jenkins, E.E. (1994). Public understanding of science and science education for action. *J Curric Studies 26*, 601–612.

Johnson, D.W. & Johnson, R.T. (1991). *Learning together and alone: cooperation, competition, and individualization, 3rd edn*. Englewood Cliffs, NJ: Prentice Hall.

Kentish, B.J. (1995). Hypotheticals - deepening the understanding of environmental issues through ownership of learning. *Austr Sci Teach J 41*(1):21–25.

Lindahl, B. (2003). *Lust att lära naturvetenskap och teknik? En longitudinell studie om vägen till gymnasiet*. Göteborg: Göteborgs universitet PhD Thesis (in Swedish).

Milner-Bolotin, M. (2001). *The effects of topic choice in project-based instruction on undergraduate physical science students interest, ownership, and motivation*. PhD Thesis, Austin TX.

Mortimer, E.F. & Scott, PH. (2003). *Meaning making in secondary science classrooms*. Buckingham, UK: Open University Press.

Niedderer, H. (2001). Analyse von lehr-lern-prozessen beim elektrischen stromkreis aus videodaten. In Stefan von Aufschnaiter und Manuela Welzel (Hrsg). *Nutzung von Videodaten zur Untersuchung von Lehr-Lern-Prozessen -Aktuelle Methoden empirischer pädagogischer Forschung*. Waxmann, Münster.

Niedderer, H., Buty, C. Haller, K. Hucke, L. Sander, F. Fischer, H.E. von Aufschnaiter, S. & Tiberghien, A. (2002). Talking physics in labwork contexts - a category based analysis of videotapes. In D. Psillos & H. Niedderer (Eds.) *Teaching and learning in the science laboratory*. Kluwer Academic Publishers, Dordrecht, pp. 31–40.

O'Neill, T. & Barton, A.C. (2005). Uncovering student ownership in science learning: the making of a student created mini-documentary. *School Science and Math Journal 105*(6), 292–301.

OECD (2005). Evolution of student interest in science and technology studies 2006, from http://www.oecd.org/dataoecd/16/30/36645825.pdf.

Osborne, J. (2003). Attitudes towards science: a review of the literature and its implications. *Int J Sci Educ 25*(9), 1049–1079.

Osborne, J. & Collins, S. (2000). *Pupils' and parents' views of the school science curriculum*. London: King's College.

Rainer, J.D. & Matthews, M.W. (2002). Ownership of learning in teacher education. *Action in Teacher Educ 24*(1), 22–30.

Ricoeur, P. (1984). *Time and narrative, vol 1*. Chicago: The University of Chicago Press.

Rudduck, J., Chaplain, R. & Wallace, G. (1996). Conclusion. In J. Rudduck (Ed.) *School improvement: What can pupils tell us*? London: David Fulton.

Ryan, M.R. & Deci, E.L. (2000). Intrinsic and extrinsic motivations: classic definitions and new directions. *Contemp Educ Psychol 25*:54–67.

Savery, J.R. (1996). *Fostering student ownership for learning*. Bloomington IN: PhD Thesis, Indiana University.

Savery, J.R. & Duffy, T.M. (1995). Problem-based learning: an instructional model and its constructivist framework. *Educ Technol 35*(5),31–38.

Sjøberg, S. (1998). *Naturvetenskap som allmänbildning*. Lund: Studentlitteratur (in Swedish).

Slavin, R. (1988). *Cooperative learning*. New York: Longman.

SOU (1996). Inflytande på riktigt - Om elevers rätt till inflytande, delaktighet och ansvar: Statens Offentliga Utredningar Utbildningsdepartementet1996:22 (in Swedish)
Stemler, S.E. (2004). A comparison of consensus, consistency, and measurement approaches to estimating interrater reliability. *Prac Assess Res Eval 9(4)*.

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