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PHYSICS LEARNING WITH EXPLORATORY TALKS DURING A MINI-PROJECT – A CASE STUDY OF FOUR GIRLS WORKING WITH ELECTRIC CIRCUITS

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Abstract. *During physics instruction with mini-projects, four upper secondary school girls decide to plan how to teach electric circuits to younger children. Their group discussions result in a conceptual change related to the concepts resistance and current. Their prior conception, built on current consumption, leads them into conceptual conflicts, and by exploratory talks they reach a new view based on current as movement with different speed. Students' ownership of learning (SOL) is increased by an instructional design with mini-projects. This gives students the opportunity to choose a unique question, to determine their own learning process, to increase their motivation and to enhance development of competence and self-confidence.*

Keywords: *physics teaching, students' ownership of learning, motivation, conceptual change, electric circuits.*

Introduction

A mini-project is a task or experimental problem or inquiry given in order to strengthen the competence in physics. A mini-project can be given in different degrees of freedom, and for different time periods. We used mini-projects that were done during two weeks, and with a list of proposed mini-projects to select from. The performance of the mini-projects was on the students' responsibility and forms of report and presentation were also decided by the students. All these features represent students' ownership of learning. This ownership of a mini-project offers an opportunity to students to use prior knowledge in other learning environments, and to develop a new type of self-constructed knowledge in broader contexts.

Objectives for use of mini-projects as instructional design.

- To give students the possibility to manage their own learning process.
- To give students freedom to approach a problem at their own level of ability.
- To give students a chance to accomplish a task without being compared to others, to solve a unique problem.
- To give students the possibility to choose intuitively a task that offers development of their individual understanding.
- To give the teacher the possibility to introduce a new type of questions or tasks aiming at a more holistic or contextual understanding and more meaningfulness.

Theoretical framework

Our basic hypothesis is that mini-projects are one way to increase motivation by increasing students' ownership. Students' ownership of learning (SOL) is the students' impact on tasks and learning environment in such a way that students have a real opportunity to achieve autonomous

learning of physics (Enghag, 2004, p. 7). Examples of SOL are students who develop own questions, own ideas for doing experiments, own ways of performance and presentation, and similar actions based on their own experiences. The students' ownership of learning has impact on their mastery orientation (Milner-Bolotin, 2001), and is fostered by a problem-based learning environment (Savery, 1996). It will give students possibilities to realise their own way of learning and to increase student influence on instruction (Enghag, 2004, p. 39).

In group-discussions, we observe how students use exploratory talks (Barnes 1971; 1973) to develop their physics competence (Enghag, 2004, p. 41). In one example presented in this paper, we see even conceptual change (Duit, 1999) happening in exploratory talks without help from the teacher. We define talks as exploratory talks if students (without the teacher) have a subject matter focused talk with special features like using language in a more exploratory fashion, using a far wider range of speech-roles, like questioning, challenging and encouraging. They use often half sentences, and fill in words into the other persons' sentences. In exploratory talks, they have taken control of the learning activity themselves and one student draws in another (Barnes, 1973).

Research methodology

In an explorative study (Enghag, 2004), we have done a qualitative theory generating abductive study with data from six cases. These cases were chosen from three different contexts, two classes with mini-projects in science teacher training at university level, two classes with mini-projects and context-rich problems in upper secondary school. These cases show a large variation about ownership, motivation and competence. During our working process, nine variables have emerged as significant. Both quantitative and qualitative methods were used to collect data into these variables. In upper secondary school, we recorded five groups with 15 students on videotapes, during the beginning of their second physics course, and at university five groups too. The video analysis was done with a category-based analysis of videotapes (Niedderer, et al. 2002) and with transcriptions of selected parts and interpretive analysis (Niedderer, 2001). As a result, we used examples from these case studies to operationally define the concepts of ownership, motivation, competence and exploratory talks. We also analysed the relation between ownership and motivation and competence in special cases. The hypothetical model from our study is "more ownership results in more motivation results in more competence" (Enghag, 2004, p. 139).

In this paper we report only one of those six cases, one female group working with the mini-project "Explain and demonstrate the series and parallel circuits of electric bulbs to a lower secondary school class.", number 16 out of a list of 18 suggestions, presented by the teacher (Enghag, 2004, p. 78 ff). We focus on questions about ownership, motivation, communication and conceptual change as one way of increasing competence.

Results of the research

Student ownership of learning fostering motivation

The four girls here called Anna, Lena, Kathy and Kristin are 17 years old and enrolled in a physics course in the natural science program. The four girls develop ownership at the beginning of their group work by talking about their decision to choose this special mini-project. In the first dialogue below, they show they have chosen this mini-project: because they want to understand the basic concepts of electric circuits and explain it to children, thus doing something useful, not only abstract calculations. Anna shows the highest ownership of this idea from the beginning. She later on has also the highest motivation:

Anna: Then you can compare to water pipes and how much goes through – how much resistance there is …
Kathy: … yes, resistance and …
Anna: I think it will be fun. You have to think for yourself and than you will understand yourself too.
Kathy: It is a basic thing to do.
Lena: I think so too, but it is difficult to explain...
Anna: But it is still more fun...maybe all the others would like to do it too …

This special mini-project was chosen only by these girls, the other groups have chosen different tasks. This gives them additional ownership; Anna's last concern turns into positive feelings. They continue to talk about the difficulties of this task:

Lena: It could be difficult to explain to them.
Kathy: Does it have to be that easy?

After this talk, they soon agree to do this mini-project as a demonstration and explanation of series- and parallel electric circuits for lower secondary school students. Their ownership of an own question (not selected by any other group), ownership of special analogies to be used, the ownership of developing their own understanding, ownership of their own decisions how to work and how to present the results, and the important feeling to do something useful give them a high motivation. We believe that this motivation supplies the crucial energy required to do a conceptual change seen by Anna and Lena. Kathy was not familiar with "the crocodile analogy". This could be a reason to her lower ownership to the question, and lower motivation during work. The group has achieved their ambition to make the design for a teaching sequence, to carry out the laboratory work and to connect series and parallel circuits. They spend a lot of effort in reaching consensus about how to explain current and resistance. Motivation is in this study operationalised as the straightforward observation of what energy the individual puts in the work process. This energy can be observed by students' choices of particular actions, persistence with these actions and effort expanded on them (Pressick-Kilborn, 2003).We use as indicators for motivation: the amount of physics talk and the amount of planning talk spent in the small group work conversation, the persistence of the work with the task, the effort the students showed in the task seen as special actions and from communication, the existence of exploratory talks. We see competence development in physics as new insights concerning conceptual and holistic understanding or practical skills.

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

Conceptual change during exploratory talks

They show examples of exploratory talks when they discuss an analogy about current as boys and girls and resistance as crocodiles in electric circuits. Exploratory talk is recognised by the way you find these two signs;

1) supporting questions that keep the talking going;

2) the repeating of the friends last word when you take over the talking and load thinking.

Kristin: But what can I say about series circuits?
Lena: It is the Christmas lights.
Kristin: Yes…if one of them goes out, the rest of them go out too. Like the Christmas

tree lights…and here are the parallel circuits…the current has two paths to chose from…and then it divides itself up and just as much current goes there as there and then the two lights shine equally bright.

Anna: *...equally bright. ..*

Kristin: *equally bright, instead of two that are dim. (pointing to the series circuit.)*

Anna: *Don't they shine with different intensities in the series circuit?*

Lena: *I kind of think they should…*

Anna: *…the last one should be less bright than the others, but maybe it doesn't?*

Kristin: *No, they are equally bright.*

The last statement of Anna and the following dialog with "crocodiles" are an excellent example of a well-known alternative conception of students called "current consumption (Shipstone, et al. 1988) or "everyday life current" (Niedderer & Goldberg, 1996). So, the students' learning process starts from this prior conception, here with the special analogy of a resistor as a crocodile eating some of the girls and boys (positive and negative charges, see figure 1):

Anna: *We might need to explain what an electron is too.*

Lena: *Boys and girls are positive and negative charges that are trying to get to each other.*

Lena: *The crocodiles like to eat people so every now and then some disappear. That is what the resistance is, the thing that stops the current.*

Here, we can see aspects of exploratory talks: Anna puts a question to the whole group and Lena gives a tentative answer, which is readily accepted. In the following dialogue, they talk about how to explain parallel circuits with their analogy:

Kristin: *Parallel circuits…*

Anna: *Is this just for current and resistance?*

Kristin: *If you have two bridges is it not easier to get across?*

Anna: *What are the crocodiles again?*

Lena: *Resistance.*

Anna: *And small bridges are also resistance?*

Lena: *Yes, and the people are the current.*

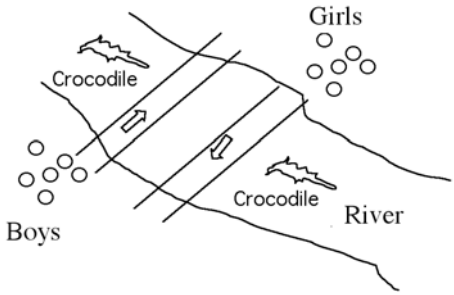

Figure 1. Lena's picture (later in her presentation on the whiteboard)

Again we see an exploratory talk going on: they all together put questions and work on their answers.

During the following exploratory talk, Lena expresses explicit her problems to understand why bulbs in a series circuit shine equally bright, so still struggling with a facet of the alternative conception "current consuption":

Kristin: *The current in this one has two choices (pointing to a parallel circuit with two lights). Unlike this one (pointing to a series circuit with two lights), which has only one way to go…that is why they are equally bright (in the parallel circuit). But why do they shine equally bright (in the series circuit)?*

Anna: *Because the current divides itself equally in half.*

Lena: But I think that is so weird. If it is divided there is only half for each one. Then it is divided again there but still we see that it isn't that way…

Lena has the initiative in telling the others about the analogy with resistance as crocodiles that consume charges. She teaches the others.

In a later part of their exploratory talks, they come back to the series circuit, and whether bulbs shine equally there or not:

Anna: Don't they shine with different intensities in the series circuit?
Lena: I kind of think they should…
Anna: … the last one should be less bright than the others, but maybe it doesn't?
Kristin: No, they are equally bright.
Lena: That is because there are crocodiles in the way and it is hard for them to get by.

Anna realises that if the charges are consumed, the bulbs will shine differently, and likes to discuss this. Kristin does not find this necessary to discuss, as she can see for herself that the bulbs shine equally bright from their own circuits. She looks and believes what she sees. Lena tries to stick to the crocodile analogy, but also realises the conflict they now have to solve: they shine equally bright, but they should not; something is missing in their view of resistance. She suddenly finds a new idea:

Lena: Wait a second…with resistance…they don't get eaten up; it is because the current goes fast.
Anna: …it slows down…
Lena: …if the current goes fast the lights are bright and if the current is slow the lights are dim…
Anna: It depends on how many electrons go through. The resistance is what causes fewer electrons to go through the lights.
Lena: … per second, it slows the speed.
Anna: Yes, that's right, it goes slower, they are not being eaten…

So, Anna and Lena seem quite sure that they have found a better explanation. They now formulate a conception which is near to Ohm's law in physics. It means to see the amount of current being related to the speed of electrons. Their repetitions of this idea shows some stability and evidence that this view now is their favourite view, and this is the reason why we speak of "conceptual change" (Niedderer & Goldberg, 1996). This does not mean that the older view has vanished (Petri & Niedderer, 2003). To the contrary, these students in their final presentation again use also their prior conception. So this might be another example, which shows parallel conceptions after a learning process. The interpretation of a conceptual change gets more evidence from their emotional statements at the end of this dialogue:

Lena: … this is really great…
Lena: … now I actually understand series circuit … it is the first time!!

The girls increased their self-confidence when they gained this new insight into the nature of resistance by their own talks.

Discussion

This study high-lights the importance of ownership of learning to get motivated enough to develop students' physical thinking. The study reports how girls in exploratory talks communicate in a way that forces two of the girls into a conceptual change of the concept resistance and current, which they use afterwards parallel to their old view of current consumption. The freedom given by our instructional design with mini-projects is necessary to give possibilities for students to communicate in exploratory talk. The mini-projects are used as an activity that are prepared in a lab session of four hours and reported in class after two weeks. In this instructional setting they are allowed to choose task themselves, and this ownership to the task gives them the motivation to develop competence in physics. Their observations of equal

brightness of bulbs in series contradicts their expectation, thus creating an anomaly of understanding. This forces them into exploratory talks that result in a conceptual change. We want to stress here that the girls themselves ask the question of how to explain current and resistance; this question does not come from the teacher. Their need to understand comes from their feeling of the anomalies within their old analogies. In their prior view, speed is not relevant for the amount of current. The girls have to sort out old analogies they have met and never really understood. To get enough time for the group discussions, and freedom to focus on their anomalies of understanding, is resulting in improved physics learning.

Conclusions

Ownership of learning includes factors that connect the students' learning process to the students' learning environment. In this meaning the ownership is an aspect of student influence. With further cases the conceptual relations between ownership, motivation and learning hopefully can be further developed and clarified. In this small group work in physics the students have got possibility for ownership from the instructional design, and two individual have ownership by their possibility to relate to earlier experiences and anomalies of understanding. Their unique question gives them high motivation, and help them to enhance and develop their understanding of the concepts resistance and current by exploratory talks and reflective thinking. They find their old view of resistance to be misleading, and develop a new view where resistance is connected to the current speed (as amount of charges passing per second), a view closer to scientific thinking.

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Резюме

ИЗУЧЕНИЕ ФИЗИКИ С ИССЛЕДОВАТЕЛЬСКИМИ БЕСЕДАМИ ВО ВРЕМЯ МИНИ-ПРОЕКТА – ИССЛЕДОВАНИЕ СЛУЧАЯ ЧЕТЫРЁХ ШКОЛЬНИЦ, РАБОТАВШИХ С ЭЛЕКТРИЧЕСКИМИ ЦЕПЯМИ

Маргарета Енгхаг, Ханс Ниеддерер

Во время изучения физики путём мини-проектов, четыре старшеклассницы средней школы решили спланировать, как объяснить электрические цепи младшим школьникам. Дискуссии в группе привели к коренным изменениям в представлениях о сопротивлении и токе. Первоначальные представления старшеклассниц, построенные на потреблении тока, привели к концептуальным противоречиям. Затем в ходе исследовательских бесед они достигли нового взгляда, в основе которого было понимание тока как движения с различной скоростью. Использование мини-проектов повышает усвоение знаний учащимися. Эта форма даёт им возможность выбирать уникальный вопрос, самим определять их собственный процесс учения, увеличивать мотивацию и усиливать развитие компетентности и доверия к самим себе. Мы использовали мини-проекты, реализованные на протяжении двух недель, со списком предлагаемых мини-проектов для выбора. Усвоение мини-проекта даёт учащимся возможность использовать прежние знания в других учебных средах и для развития нового типа самоконструироемого знания в более широких контекстах.

Ключевые слова: преподавание физики, усвоение знаний учащимися, мотивация, концептуальное изменение, электрические цепи.

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