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Context Rich Problems in Physics for Upper Secondary School

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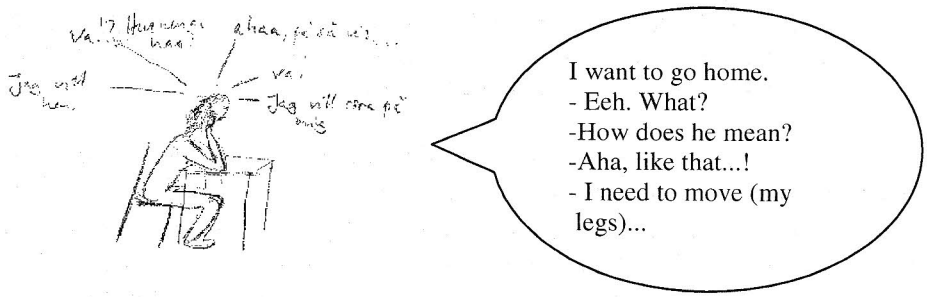
ABSTRACT *This paper reports observations from one of several case studies of students working with context rich problems (CRP) and mini projects (MP) in an upper secondary school class. This small group work concerns the problem-solving of a context rich problem during an 80-minute lesson of physics. We have video-filmed a group of girls during their work, thereafter we have transcribed and analysed the videotape from how group discussions in physics influence the students' learning. Interactions between students during the group discussion are of different types. When it comes to development of conceptual understanding the girls go into exploratory talks, a kind of talks described by Douglas Barnes in the 1970s. The amount of talk within different categories of talk, how the amount of talk in different categories is divided amongst the girls, and their steps in the problem-solving are specified. The importance of time for reflective talks in physics to enhance learning is high-lighted by quotations from the girls' discussions.*

KEY WORDS: *Elementary science, constructivism, culturally and linguistically diverse students, student characteristics*

Introduction

In the educational purpose to increase students' interest in physics at school and university, Context and Conversation in Physics is in progress as a cooperative effort between Mälardalen University and Umeå University. The physics courses in Swedish upper secondary school are found to be very demanding with an increasing amount of students dropping their courses. Two physics courses will cover the classical and modern physics on a calculus based level. This study reports observations from case studies of students working with context rich problems (CRP) and mini projects (MP) in an upper secondary school class. At start of the study, the students went through a physics test and gave their view of school physics as a written statement or/and a drawing. Here, we found a big shift from students mentioning physics in secondary school as fun and easy, to physics in upper secondary school as boring, difficult and with lack of time for reflections and physics talking, even though students still find physics interesting in itself.



"Booooring. Often rather difficult as well. Many parts are interesting if you have time to think of it, but that time does not exist. It is all about understand as fast as possible, and then study for the test, and then to move on." (Female student).

In order to study how group discussions in physics influence students' learning and their ownership of learning, we introduced CRP and MP. We recorded five groups, totally 15 students on video tapes during the beginning of their second physics course. The video analysis has been done with category based analysis of videotapes and with transcriptions of selected parts (Niedderer, 2000, 2002).

Our study focus on group behaviour and individual activity within the groups, how this reflects in engagement of the task and perception of the question at issues, and any difficulties in reasoning and understanding of physical concepts. We also studied the students ownership of learning (Milner-Boloti, 2001; Savery, 1999; Enghag, 2004). In this paper, we report how communication takes place in a female group solving the CRP called "The Clay."

Student's Ownership of Learning.

The concept students' ownership of learning (SOL) includes student ownership given by the instructional setting: content, question, planning, performance, result and presentation. Student ownership of learning also includes choice of partnership in groups and choice of activities concerning where, when, and how. A main point is the ownership to communication; i.e., possibility to discuss with others, possibility to use media and teacher, and to allow emergence of own questions. Concerning control and responsibility, possibility to take informal leadership, to negotiate, or to follow the stream. From this view ownership has to be seen as a possibility or power for the students.

Students' ownership of learning (SOL) is described in two levels (Enghag, 2004):

Group level: The SOL is decided by the design of the task. The choice of task, the performance (when, how, where), the level of results, and how to present and report them have to be decided by the students themselves.

Individual level: A person's experiences and anomalies of understanding have created unique questions that can high-light aspects of the task that drive this person to be very active and motivated. This gives the person a high individual learner ownership.

Method and Design of the Study

This small group work concerns the problem-solving of two context rich problems during an 80-minute lesson of physics. We have video-filmed a group of girls during their work, thereafter we have transcribed and analysed the videotape from how group discussions in physics influence the students learning and their ownership of learning.

We have categorised the communication into the variables interest, motivation students' ownership of learning, and development of competence (Enghag, 2004).

Interest before start is given as the girls' view of physics and their result in a competence test, including 15 questions to test their formula calculation ability, their conceptual understanding, and their contextual or holistic understanding. Their motivation is decided from the amount of words categorised as physics or task planning (Niedderer et al, 2002; Enghag 2004), but also from persistence with the task and effort seen as special actions (Pressick-Kilborn, 2003; Ryan & Deci 2000).) These special actions could be the existence of exploratory talks (Barnes, 1973, 1976; Barnes &Todd 1977), or internal teaching (Enghag, 2004), but also other types of actions as making creative suggestions to the group, or making measurements.

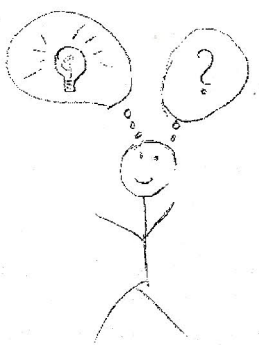
A context rich problem is a physics problem in the context of a story, given to a small group of three or four students. CRP was developed by the University of Minnesota. (Heller, Keith, & Anderson 1992: Heller & Hollabaugh, 1992). The design of the CRP encourages students to use a logical problem-solving strategy instead of plain formula driven random search strategies.

The CRP "The Clay": description of the task

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

Give a report of assumptions, calculations, and conclusions.

Results



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

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

Lena: "*Booooring. Often rather difficult as well. Many parts are interesting if you have time to think of it, but that time does not exist. It is all about understand as fast as possible study for the test, and then to move on*" *(female student.)*

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

The physics test with five questions in formula calculations, five in conceptual understanding, and five in holistic understanding could give maximum (5, 5, 5) points. The three girls did: Anna (4, 1, and 4), Lena (4, 3, and 4), and Kathy (4, 2, and 5). They are all strong in holistic understanding, but not that accomplished in conceptual understanding, a situation that is a natural result of the teaching strategy of physics in secondary school as being more descriptive than focused on problem solving. They show a very positive attitude towards the session with CRP work. They are almost excited to start with the task and there is some competition in the air as the other groups are doing the same task;

Anna: They are ahead of us. (Can't find what she is looking for in the formula book.)

The girls have to face the problem that this is not a commercial resistor they have met before. Could it be compared with a wire? They also have to face the unknown material constant resistivity. Kathy discusses whether the length has any impact at all, as the volume is constant. Anna and Lena have this feeling that as the length increases, and the cross-section changes the resistance will be effected. They compare to water that will come through a tube. They find the area formula, but do not know the concept resistivity. As the same symbol is used for density, they discuss density. As the material is the same and the volume constant, their arguments function despite this anomaly. The electrical resistance of a wire would be expected to be greater for a longer wire, less for a wire of larger cross sectional area, and would be expected to depend upon the material out of which the wire is made. Experimentally, the dependence upon these properties is a straightforward one for a wide range of conditions, and the resistance R of a wire can be expressed as

$$R = \frac{\varrho \cdot L}{A} \qquad \text{L= length, A= cross section, } \varrho \text{ = resistivity).}$$

In this situation they try to describe the relationship algebraically. Now, Kathy has problem with the abstract language of algebraic notation, and Lena teach her how to think. Anna is sure of the solution, but they try to follow each other way of thinking, and suggest a final result.

The CRP problem-solving timeline is presented in Table 1.

Special forms of group talk

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

Anna: It was something about how to use Ohm's law...

Table 1
The CRP Problem-solving Timeline

Category	Time	Individuals
Realises the volume is constant	6.25	Kathy: But does it really matter how long it is? I mean, its width decreases but it is the same resistance…the volume is the same?
Realises that R increases with increased L	6.40	Lena: Yes…Yes that's right…it becomes smaller too. Anna: It gets wider.
Realises that R decreases with increased A. (inverse proportionality)	6.40	Lena: It is short and wide, short and wide gives less resistance than long and thin.
Realises that several variables affect A.	8.54	Lena: I actually think that it can be 1000 W, it is not just the increased length because the width is also smaller.
Realises that the resistance is the same	7.25	Anna: Yes, if it is the same composition as the modeling clay.
recognises the formula.	9.06	Lena: There is an area formula.
Realises that ϱ is the symbol for resistivity.	9.50	Anna: It has something to do with length and area. Lena: Here it is… Anna. What it the constant then…ϱ Lena: It is ϱ that is density. Anna: Density can be calculated. One has it.
Realises same symbol for several quantities, density, resistivity, ϱ	10.53	Anna. (looks in the formula book) They didn't have modeling clay. Otherwise they usually have lots of weird things. Lena: Is there anything like it?…then you could guess…Is clay in there? (Anna looks in the formula book)
Realises the physical ramifications of the formula	12.06	Lena: I still think it will be this way. But yes… Anna: But can't we set this to 1, radius 1 to the length to 1 if…or we set x, we calculate with x and then set x by something-and then we can to something, I don't really know what. Lena: Yes, that is good.
Can describe the relationship algebraically	17.10	Anna: We have to write it down… Lena: ..it looks like this.. Anna:...We need to call it something. Don't you need to write 21… Lena: Yes, 21 divided by ½A.

Lena: Yes, that's what it was.
Anna. ..it was dependent upon the length and the area…
Lena: ..cross section.
Anna: .. Here it is R that is resistance.
Lena. ..Yes, but then you have to have…
Lena: ..Yes…we can write the formula too. Do you recognize it?
Anna: .. Yes it has something to do with length and area in the formula.
Lena: There it is. Do you recognize it?

Another type of communication seen is what we call internal teaching. Lena is pretty sure of her knowledge that resistance is increasing with the length, and goes

for explaining the phenomena to Kathy who has never heard about it....

Kathy: This is stupid, I don't think there should be any change because....
Lena: But, if you have a copper wire that is this long (stretches out her arms), then there is a lot of resistance. But, if it is short and thick (uses her hands), then there is little resistance.
Kathy: Yeah, I guess.
Anna: Then there is room for many in the tub...You need to think about water, like you did in ninth grade.

They are very polite to each other and give each other confirmations that they have got the point of the other person's ideas:

Kathy: But, I am thinking about a really long rope that you fold up.
Anna: Then lets fold it up !
Kathy: Yes, I know, but I assume that it is the case.
Lena: O.K., so that's how you think.

Another example of this phenomenon:

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

Motivation and amount of different types of talk in the group

To give a dynamic picture of how the talk is developing by time, we divided the amount of talk during the session in three parts.

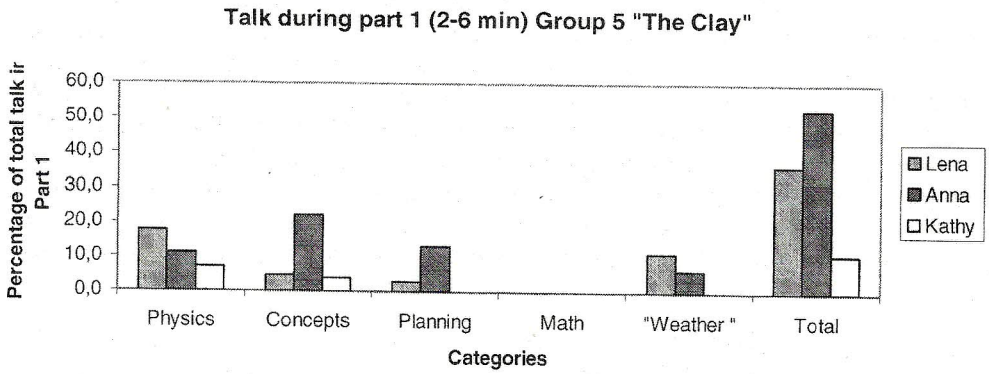


Figure 1. Individual amount of talk divided into categories (Percentage of total talk in each category), Part 1: 2-6 min.

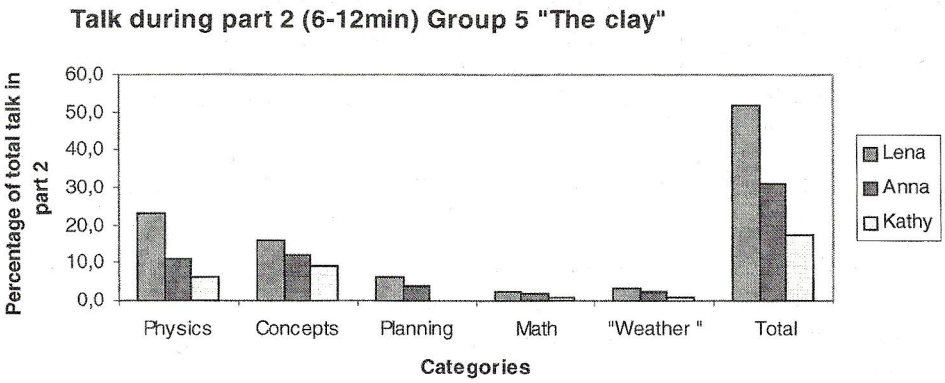


Figure 2. Individual amount of talk divided into categories (Percentage of total talk in each category), Part 2: 6-12 min.

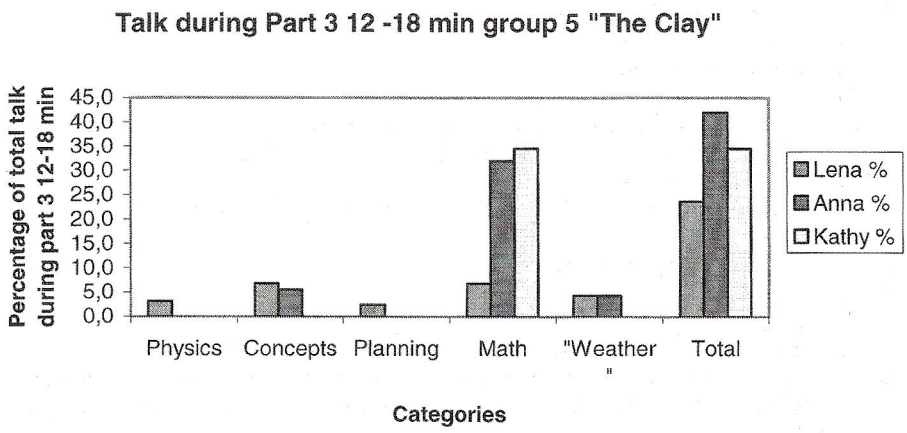


Figure 3. Individual amount of talk divided into categories (Percentage of total talk in each category), Part 3: 12-18 min.

From Figures 1, 2 qnd 3, we see how Anna and Lena have the initiative and become dominant in the physics and planning talk. We can see how Kathy's talk is increasing during the three parts of the session, and how it increases when it comes to mathematical problem-solving. They are all very focused on the task, only 12 % of the talk concerns non-task talk. In total, Lena does 40% of all talking, Anna 35%, and Kathy 25%, which gives the group an equal profile when comes to communication. They do not spend much time on planning (8%), but the planning category is not equal in the group. Lena takes 67% of the talk in this category, Anna 25%, and Kathy only 8%. This gives Lena strong ownership and motivation to the task.

Persistence with the task

They work hard and the total time spent on the problem is 30 minutes, but the problem was solved after 17 min.

Table 1
Percentage Amount of Words Used in Categories and by Individuals.

Percentage of words	**Lena**	**Anna**	**Kathy**	**Percentage of words per category**
Physics-physics concept	40%	33%	27%	**40%**
Result-planning	67%	25%	8%	**8%**
Talking that is unrelated to the assignment	46%	41%	13%	**12%**
Mathematics-Formulas	33%	37%	30%	40%
Total	**40%**	**35%**	**25%**	**100,0%**

The group spent 40% of the talk of physics and conceptual talk, compared to 40% of mathematics talk and 8 % of planning talk. This must be seen as a strong result for the CRP as an instructional design. We see improvement of conceptual understanding of resistance. Their experience of anomalies of understanding comes into the light, and their internal teaching helps all three to understand the problem. The mathematics is a large part of the problem, and here the difficulties come to the surface, and they discuss and agree finally on the solution.

Discussion

The group reported in this paper is one of totally 15 in the study so far. To compare with other groups, we find that in small groups working with CRP, a main part of the time is used for talking physics even in low performing groups. With three pupils in a group all are active, but with four one of the pupils tends to stay out of the discussions. Physical models are not understood entirely as models by the students, but numerical calculations out from models are done to verify their reasoning. Analogies are used in high performing groups in their reasoning. In a high performing group, exploratory talks are used between equally strong students, and they teach each other until they all agree on the answer. In a low performing group, the teacher becomes very important to be the one who stimulates the group to go further into the problem, as the connection between mathematical problem solving and the physics problem are not obvious to the students. In the groups studied, all students but one evaluates CRP as fun, interesting and a nice variation in the traditional lessons.

" It was fun to work in small groups. There you can discuss and get other ideas than your own. It didn't feel as something horrible, if we didn't manage to solve the problem. Nice with plenty of time. Fun with the task that was different, not as the traditional and boring "(female student.)

CRP is one way to give students the freedom to communicate, and we found this to be the key to development of understanding. As unique questions are crucial for individuals to get influence of their anomalies of understanding, we find it important that the students are given several CRPs to choose from, given as long time as possible to work with each problem. The chances for conceptual changes increase with the time the group of students communicate and reflect over the task.

In this study, we have integrated the CRPs into the classroom instruction by decreasing the time for textbook exercises. Group work with CRPs took part at the end of a section teaching Electrical Circuits in a physics course. The students were not examined individually, but the result for each group was discussed with the teacher, and the group gave a written report of their result. It is also possible to introduce CRPs into the classroom instruction examined as a specific activity separated from traditional teaching. The CRPs could also be a very useful part in the studies of physics at university level. At Mälardalen University, CPRs are in use regularly in physics courses for students in aeronautical engineering. In this course, 20% of the course time is used for CPRs as a special activity. Also in courses for physics teacher education, CRPs are in use.

Conclusions

Many students feel that they want nothing more than to learn, but they end up with disappointments as they cannot keep up with the speed and demands upon them. One way to contribute to learning of science is to introduce more student ownership of learning. To meet the future, this more humble attitude towards the students' needs could be a way that can help students find science relevant to them. We focus in our study on how group discussions in physics influence the students learning and their ownership of learning. The possibility to communicate in reflective and exploratory talks around the physics problem makes the students to face the individual difficulties they have. The increased student influence impact on learning results.

Acknowledgments

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