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CONTEXT RICH PROBLEMS AS AN EDUCATIONAL TOOL IN PHYSICS TEACHING – A CASE STUDY

Abstract. *We present a case study, in which we used context rich problems as an educational tool in a university level physics course. The students worked in groups of three to four when solving these problems, which provided them with an opportunity to discuss physics together at their own level. Video recordings of groups working with the problems allowed us to study how different groups functioned and also to look for what is known as exploratory talks. This form of communication was interpreted as situational interest on the part of the students. A questionnaire at the end of the course, and interviews with a few of the students after the course, revealed that the students considered that context rich problems facilitated understanding of physical concepts and made physics more interesting.*

Key words: *context rich problems, university physics, cooperative groups, teaching methods, science education.*

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Introduction

In Sweden, as in many countries in the Western world, there is diminishing interest in studying science and engineering. Among these subjects we have physics. Still, there is continues need of people educated in physics to participate in the solution of problems in our modern society, e.g. connected to energy supply on a global level and environmental issues.

In order to attract students to physics at university level, complementary instructional settings in physics education are needed in addition to the established ones. New methods also enlarge the educational toolbox for professors, thus benefiting all students of physics. We therefore present a case study on the use of context rich problems (CRP) (Heller & Hollabaugh, 1992) as a complementary educational tool in physics teaching. We have used CRP based on the hypothesis that it promotes peer communication, thereby encouraging all students to take an active part in problem solving. One base for this educational tool is the cooperative group as a structural approach to create or organizing a social interaction in the classroom (Kagan 1989/1990). This is to be seen as an alternative to a competitive individual work. In the cooperative group a collaborative behaviour develops when all members of the group work together on each step in the problem-solving process. All students in the group, independently of skills, are reported to benefit from this instructional approach (Heller, Keith, & Anderson, 1992). We also believe that it promotes the use of physical concepts in dialogue and creates situational interest (Pintrich & Schunk, 1996).

CRPs are physics problems presented as stories, which take place in an everyday context and with the student as a leading character[1]. The importance of an everyday context has been emphasised in research (Park, 2004; Whitelegg & Parry, 1999). The problem should be complicated enough to make it impossible for one person to solve single-handedly (at least in the case of less skilled students) but possible for a group of three to four students to solve together. Such problems encourage students to use an organised and logical problem solving strategy as opposed to a mere formula driven random search (Heller & Hollabaugh, 1992; Heller, Keith, & Anderson, 1992).

When the students are engaged in problem solving during group discussions, they use language in a more exploratory fashion with a wider range, such as questioning, challenging and encouraging (Barnes, 1973; Barnes & Todd, 1995). They often use half sentences and complete other persons' sentences. When this happens, the students have taken control of the learning activity, and one student draws another into the discussion. This is defined as exploratory talks and we interpret it as indicating situational interest on the part of the students.

In this paper we report on how CRPs provide an opportunity for students to discuss physics in small groups. We have also studied interactions among different student groups and attempted to characterise various types of group behaviour. The students' own views of CRP were investigated by a questionnaire at the end of the course.

Methodology of Research

In an introductory physics course of 7.5 ECTS (European Credit Transfer System) points for aeronautical engineering students, 40 percentage of the teaching time was used for traditional lectures and 20 percentages for laboratory experiments. Furthermore, three 135-minute lectures were used for solving CRPs and equally for exercises (problem solving of end-of-chapter text book problems, both by the teacher and individually). This means that approximately 20 percentage of the total time in the classroom was used for CRPs. For the CRP sessions the students were divided into groups of three or four. The groups were formed on the basis of the students' previous performance in the engineering programme in accordance with suggestions made by Heller and Hollabaugh (1992), who recommend that a group should consist of one overachieving, one average and one underachieving student. Groups with female students should include at least two.

Problem solving strategy

At the start of the sessions with CRP, a problem solving strategy based on that described in 'The ideal problem solver' (Bransford, 1993) was introduced and distributed to the students. This strategy was to be used when solving the problems and consists of five steps:

1) Identify the problem and opportunities [to do something creative]
2) Define goals
3) Explore possible strategies.
4) Anticipate outcomes and act!
5) Look back and learn

Each group was asked to write down and hand in one copy of the solution to the problem based on this strategy.

Methods of data collection

The data collection took three different forms, namely video recordings, a questionnaire and interviews. All video recordings are from the same course. Three groups were video recorded during

[1] http://groups.physics.umn.edu/physed/Research/CRP/crintro.html

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the problem solving process, from which we selected one problem for study. The three groups studied solved the same problem.

During the final lesson of the course, all students were asked to fill in a questionnaire regarding their experience of CRPs. The questions focused on their views on whether CRP made physics more interesting and whether conceptual understanding became easier. A seven-point Likert-scale was used. The questionnaire was employed on a total of 55 students. Finally, four students were interviewed in order to deepen our understanding of the students' experience. An interview-guide was constructed based on the responses found in the questionnaire. All the interviews were transcribed.

The problem and questions used in the video analysis

The studied CRP: *The Drink*

You are with a friend at the "Gondolen" restaurant in Stockholm and have just ordered a drink before dinner. While you are having the drink and looking at the "Stockholms ström" river, your friend is philosophising: - Are you as a physicist able to tell me how many ice-cubes are needed to cool this drink to an appropriate temperature?

In the video analysis we focused on some specific issues:

1) How does the group function? Is there a peer communication? Do all students take active part in the solution? Is one group member in charge and leading the process? Are they trying to reach consensus? How do they cooperate?
2) How is the problem solving process made visible? Is the problem-solving path a definite and expert-like one or more in the nature of a random walk towards the solution?
3) In their discussion, how do the students introduce and handle different physical concepts necessary for the solution?
4) Do the students appear to be interested in the task? Do they devote time to activities other than the problem? Do they express a concrete interest in the task?

Results of Research

The video analysis

From the video recordings of the three different groups solving the same CRP, a complete transcription of the dialogue of one of the groups was made. In the case of the other two groups, résumés of the conversation were written as a support for the analysis. As indicator of peer communication, student activity and interest in the task, we looked for exploratory talks (Barnes, 1973) in the transcript and résumés. We also hold that exploratory talks in the discussions mean that the group is taking steps towards understanding physics (Enghag, Gustafsson, & Jonsson, 2006).

Common features for all groups

All groups consisted of male students and managed to solve the CRPs. They were clearly focused on the task. No time was used for discussion of issues irrelevant to the physics problems. Thus we interpret that all the studied groups were highly motivated.

In all groups the solution process took around 40 minutes. While the problem-solving path differed between groups, they all had a more or less clear strategy. Jumps between necessary "expert" steps in the solution occurred, but not always in a logical sequence.

Peer communication and Group characteristics

The Solitaire group

One group, called the Solitaire group, consisted of three students who worked rather individually. From the video recording it is clear that one of the three is the skilled one and practically solved the problem single-handedly. One of the others assumed a social role and initiated discussion, for example by asking questions. Discussions were primarily between the skilled student and the social student. The third student showed less initiative and apparently had difficulty understanding the task. He suggested that "writing down what happens" could solve the problem. That an actual calculation can be done and a numerical answer found was not clear to him initially, although he showed interest in the task and worked at his own level.

In this group, where the solution was reached mainly due to the work of one student, the proposed solution strategy was followed in a rather straightforward manner. Initially, there was a short discussion about what part of physics the problem is related to, after which it was concluded that the mass of the ice is the goal of the calculation. There is no evident problem in the solution process. It is interesting to note that concepts that relate easily to everyday life were evaluated in that context. For temperatures that had to be estimated, this group as well as the other two referred to "room temperature", "refrigerator cold" and so on. This is in contrast to more abstract concepts such as specific heat or latent heat, which, as far as the students were concerned, were merely values in a table. In this group, we did not find many exploratory talks in the discussions.

The Discussion groups

In the other two groups, which we called Discussion groups A and B, an active discussion took place between all students. Group A, from which the transcription was made, comprised four students and group B three students. In these groups, all members contributed to the discussions and treated each other as peers. They all contributed to the solution by providing input and taking an interest in different aspects and questions. Compared to the Solitaire group the path towards the solution was not as straightforward, although a logical structure was nevertheless visible. All necessary parts of the solution can be clearly recognised in the discussion: the identification of the calorimetric sub-processes and the equilibrium statement, the estimates of essential parameters, the search for necessary data and finally a validation of the result. Understanding of the problem and its physics, the modelling as well as discussions of assumptions that must be made are interlaced and took place during the first 20 minutes. Then there was a rather clear phase of finishing the model, followed by a short search for necessary data before making the calculation. The final 10 minutes were devoted to a discussion of how many pieces of ice the calculated mass corresponded to.

When a concept or parameter entered into the discussion they talked it through. Examples were found in these groups where physics models were not only described as formulas but also expressed verbally. At one point, one of the discussion groups formulated $Q=mc\Delta T$ and recognised that it meant: *"the lowering of the temperature of the water [drink] gives the energy needed to be removed from it"*. Such examples indicate an understanding of the physical interpretation of formulas, and these examples where not found in the Solitaire group.

The discussion in this group was more open compared to the Solitaire group and included many examples of exploratory talks, indicating situational interest. It is easy to find examples of how they explored the physics related to the problem:

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Example 1:	Discussion group A. After approximately 5 minutes:
Student A1:	*Doesn't it matter how many sides there are (on the piece of ice)? Do you understand what I mean? If the ice is in contact with the liquid? If you have only one piece or many? It will be quicker with many pieces, but it is only the speed.*
Student A2:	*It must have something to do with the speed, the volume is the same.*

Here they had a discussion of the process speed and what influences it. They returned to this ice discussion ten minutes later with the realisation that it is not the time that matters but the amount of ice needed to reach the equilibrium state:

Example 2:	Discussion group A.
Student A2:	*We will find the smallest amount of ice needed to reach this temperature and it will have melted completely and become water.*
Student A1:	*It feels …wrong.*
Student A3	*What?*
Student A1:	*After the melting procedure is finished…yes*
Student A2:	*But that is probably what they want to know.*
Student A3:	*Otherwise it is the time that matters.*
Student A2:	*But you always have more ice than necessary… otherwise you have to stick the ice to something and you cannot measure it…and look how much is melting.*
Student A1:	*It is true…what you say is true!*
Student A4:	*…but it is simply ice that is melting that…*
Student A1:	*It is exactly that amount of ice that is found at equilibrium…*

In this passage we find an exploratory talk characterised by repetition of words and phrases used by others, invitations to discussions, evaluation of other students' statements and use of fragmented sentences. Such examples also exist in the other discussion group (Group B), thus demonstrating situational interest in the group.

In the case of the discussion groups, we also noted that the initial discussions concerned the less complicated questions such as an appropriate temperature and volumes, which made it easy for everyone to form an opinion and present arguments. This facilitated continuation of the discussion in more complex areas such as energy equilibrium and phase transition.

The questionnaire

The questionnaire contributed further information and data and the results clearly show that context rich problems were much appreciated. Since we wanted to investigate how well CRP function as a educational tool from a student perspective, we were interested in the student position, for or against, if CRP facilitate understanding of physical concepts and makes physics more interesting and also how much of CRP should be used in the learning process.

The questions, which were answered on a seven-point Likert-scale, were:

- "I prefer the following combination of problem types".
- "CRP facilitates understanding of physical concepts compared to text book problems, TBP".
- "CRP makes physics more interesting".

The first question was asked from that we had equal parts in time devoted for the two types of problem solving exercises; CRP and TBP. Do the students prefer any of the two kinds of exercises?

The third question was formulated with physics as a general subject in mind, but from the interviews it is obvious that students relate "interesting" compared to TBP. See further the student comment under "The interviews". Figures 1-3 show statistics from the questionnaire.

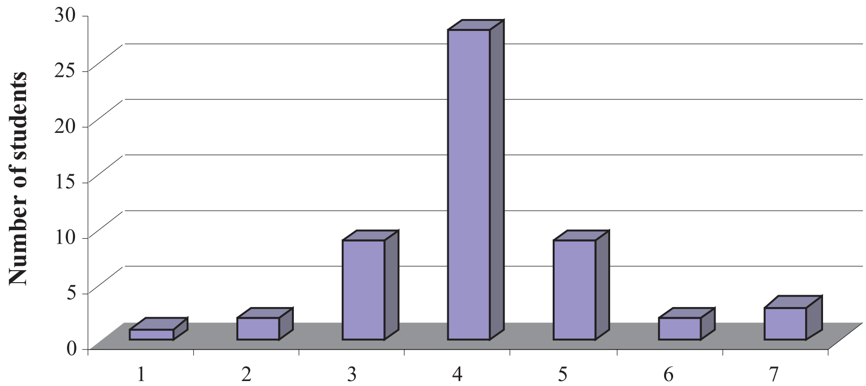

Figure 1. **The answers to the statement "I prefer (on a seven-range Likert scale), the following mix of problem types (1 = Only CRPs, 7 = Only TBPs)."**

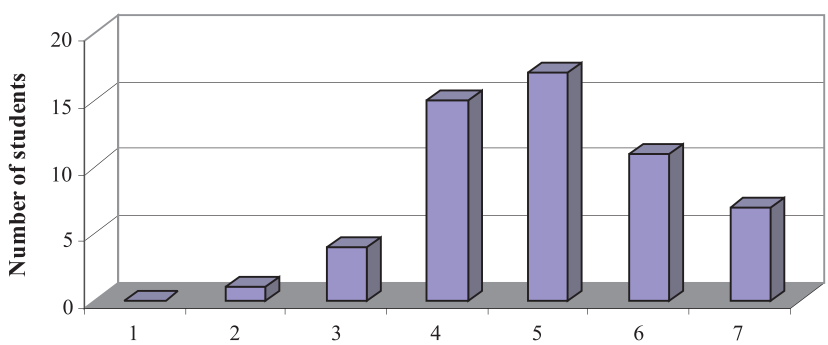

Figure 2. **The answers to the statement "CRPs facilitate understanding of physical concepts compared to TBPs (1 = absolutely not, 7 = absolutely)."**

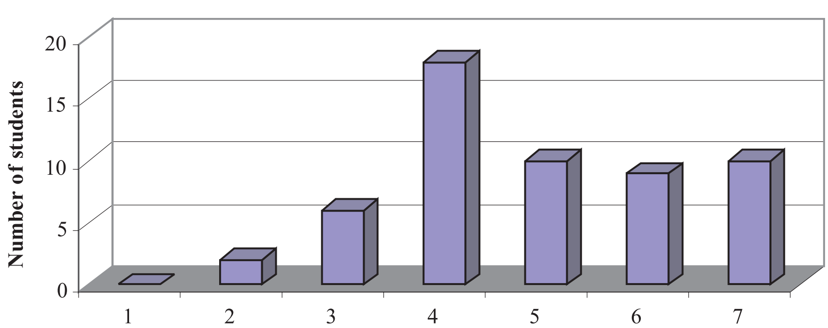

Figure 3. **The answers to the statement "CRPs make physics more interesting (1 = absolutely not, 7 = absolutely)."**

We performed a statistical significance test on the data sets presented in figures 1 - 3 in order to

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determine whether the students' responses to the questions diverged from the null-hypothesis that the responses are normally distributed, with a mean value m = 4. To test this we used a t-test with n-1 degrees of freedom (in our case n = 55). The significance test on the data set corresponding to figure 1 shows that the data are not significant on the 1 % level. In this case we accepted the null-hypothesis, which means that the students prefer a mixture of CRPs and TBPs. The data presented in figures 2 and 3 are found to be statistically significant on the 1 % level; therefore we rejected the null-hypothesis in these cases, indicating that students believe that CRPs facilitate the understanding of physics concepts and make the study of physics more interesting.

Another question in the questionnaire was "What is good and bad about CRPs?". Alternative answers to the question were pre-constructed by the authors, but there was also a possibility for the students to give their own suggestions. What the students found positive (see table I) was that CRPs gave them an opportunity to discuss physics, to solve problems together and that the questions were open in character. They were also of the opinion that CRPs are realistic.

Table 1. The answer to the question "What is good and bad about CRP?".

Good		Bad
50	To be able to discuss physics together	3
51	Solve problems together	1
46	Open ended problems	1
26	Answers to exercises are not included	19

The interviews

The interviews with the students strengthen the conclusion from figure 3 that CRPs make physics more interesting. The interview focused on questions such as:

In CRPs open-ended questions are often used. The students appreciate this. What, in your opinion, is the reason?

A student answer from the interviews: *'It is much more interesting to do calculations with questions like these. Having to sit down with a textbook, with the same questions all the time is no fun. It is much more interesting to meet this type of everyday problem. If you realise, oh it [such problems] can be solved like this and so on, not like problems in the book, which are more mathematical. If you have some numbers, you just put them into some formula [for the textbook problems]'.*

The interviews also provided more information on what a difficult problem means to the students. Problems are difficult if:

- they must be solved in several steps
- you lack competence in the area
- too much information is provided (you must select and know what is relevant)
- too little information is given (you must understand that certain information is missing and know where to find it).

Question: *What is the most common reason why a problem is considered difficult?*

A student answer from the interviews: *'Because it feels difficult. One has too much information for example. One thing solves another thing and then it is put together to give a new answer, and then it should also be applied to a third thing, after which unknowns are to be put into the fourth and so on. Things like that are, at least in my opinion, difficult. If you have too much information at the start, so to speak.'*

We also gained information about what the students mean by realistic problems. For them realistic problems are problems from everyday life and of relevance to them, for example in the context of aviation.

Conclusions and Implications

We found that, despite the characteristics of the various groups, they all had an active communication, completely related to the physics context and physics concepts. They all managed to solve the physics problems and we found that the use of CRPs was generally appreciated, the main reason being the opportunity to work in groups and discuss physics with peers. From the questionnaire and the interviews it is clear that CRPs make physics more interesting and facilitate understanding of physics concepts. The students' view on what constitutes a complicated problem confirms the findings of Reif (1995) that the two main obstacles for students are lack of information and eliminating unknowns through solving sub problems (solution with several steps).

By means of the video recordings we observed how different groups employ different strategies to solve the problems, from a group where one skilled person leads the group through the solution (Solitaire group), to a situation where all group members discuss as equal peers and seek the solution together (Discussion group). In the Discussion groups we found many examples of exploratory talks, which we interpreted as situational interest when solving the CRPs. In these groups we also found examples of verbalisation of physical formulas, indicating an understanding of physics. In the Solitaire group on the other hand, we did not observe many exploratory talks.

As being a case study, further investigation should include more groups to look for other possible group characteristics. Also an opportunity should be introduced to the groups to choose from several different CRPs at each problem-solving occasion. Thereby the individual ownership of learning for the students would increase and better learning and motivation would be at hand (Enghag & Niedderer, 2007). It would also be interesting to apply CRPs to other science subjects, such as chemistry and biology.

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