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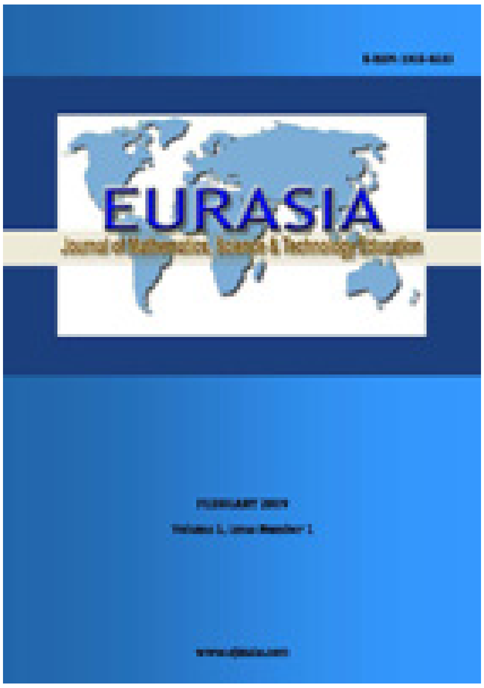

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Problems and Possibilities with Centering Physics Teaching around Student Discussions

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Group discussions were introduced in an introductory physics course at the National University of Laos. About 200 students discussed two qualitative questions in groups of 3-4 students. This was followed by whole class discussions. We examined this new method and identified problems and possibilities with it. Seven groups were recorded and students and teachers were interviewed. Findings indicate that many students had problems with mechanics concepts. In the group discussions most students co-constructed an answer. However, the students in general did not seem to come to an understanding of the physics concepts, and in class follow-up discussion proved to be an essential tool for a better understanding. To improve the discussions, the students need more time and should also be informed about the essentials of working in groups.

Keywords: changing teaching, co-construction, group discussion, mechanics

INTRODUCTION

Physics teaching in Laos is very formal and theoretical both in high schools and in universities. The teachers only explain concepts with words, and write or draw pictures on the blackboard and most of the teachers do not use demonstrations. The students spend a lot of time solving end-of-chapter problems from the textbook individually. Many science students in Laos do not find physics interesting and many of them pass physics courses at the university level without an acceptable conceptual understanding of physics (Luangrath & Pettersson, 2008).

To study with group discussions seems to promote both interest and understanding of concepts and principles of physics (Ho & Boo, 2007; Springer, Stanne & Donovan, 1999; Benckert & Pettersson, 2008). Students then get a chance to discuss together about physics and they can exchange ideas with their friends and with their teachers.

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All freshman students in the Natural Science Faculty at the National University of Laos take a course in physics. The students have one lecture and one tutorial each week, and a lab session every second week. The traditional tutorials include various exercises taken from the textbook. In the tutorials the teacher first explains some important points from the last lecture and shows how to solve some problems. After that the students solve problems and answer questions from the textbook on their own.

In 2010 the tutorials for the freshman students were organized in a somewhat different way to include some group discussions. The tutorials started as before but instead of solving problems on their own, the students were organized in small groups that solved problems together. It is this new arrangement of the tutorials with group discussions that are studied and described in this paper. Our main aim is to describe problems and possibilities when the physics teaching is changed to include more group discussions.

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State of the literature

- A lot of studies have investigated how students solve problems in group discussions. Many studies found that better problem solutions emerged through collaboration in small groups than by individuals working alone and the group discussions improved the problem solving performance of students at all ability levels.
- Many papers discuss students' understanding of physics concepts. The most common observed alternative conceptions are related to concepts of mechanics.
- There are some studies that focus on the group functioning. Most of these studies show that to get well functioning groups the students were assigned rotating group roles to empower the students to take actions they would not spontaneously perform.

Contribution of this paper to the literature

- This paper investigates what problems and possibilities arise when the physics teaching in Lao PDR is changed to include group discussions.
- The paper offers new insights into the role of the conflicting ideas in group discussions. We show several examples of group discussions leading to correct or wrong answer to the questions.
- The paper emphasizes the importance of teaching about working in groups and also to follow up group discussions in the whole class.

Background

Group discussions in physics

To learn is to transform new ideas presented in a social situation (e.g. a teacher talking, a parent explaining, a group of friends talking) to an individual meaning making (Mortimer & Scott, 2003). If the student find what is said to be unfamiliar the learning is demanding and the student has to work a lot with the ideas. Barnes and Todd (1995) point out that one of the most important ways of working on understanding is through talk. Small group talk encourages exploration of ideas and group discussions can be a good way to work with demanding and unfamiliar ideas. Gödek (2004) explained that teachers could describe discussion techniques to encourage collaborative learning, and they could activate children's thinking by letting them examine ideas together.

Group discussions have been used in physics teaching to enhance student learning (Alexopoulou & Driver, 1996; Benckert & Pettersson, 2008; Gautreau & Novembsky, 1997; Heller & Hollabaugh, 1992; Heller, Keith, & Anderson, 1992; Tao, 1999). Gautreau and Novembsky (1997) describe a small-group approach to physics learning where they find that a "second teaching" takes place in the small groups following the "first teaching" by the instructor. Benckert and Pettersson (2008) found that group discussions could lead to stimulating and learning discussions which helped the students to improve their knowledge of physics concepts. On the other hand, they also found that too little knowledge of actual physics and bad functioning of the groups could hinder a fruitful discussion in the group. Heller et al. (1992) found that better problem solutions emerged through collaboration in small groups than by individuals working alone and the group discussions improved the problem solving performance of students at all ability levels.

Tao (1999) describes the benefits of peer collaboration to be articulation, conflict and co-construction. In peer collaboration the students have to verbalize and make public their intuitive and emerging ideas, they have to articulate their ideas. The students sometimes disagree with each other and to resolve the conflict they have to justify and clarify their positions. Finally, when the students work on a problem they can co-construct shared knowledge and understanding. Tao analyzed if the students in the dyads disagreed in their approaches to the task and if they co-constructed the solution. He found that whereas co-construction may lead to the correct as well as to the wrong solution, conflicts nearly always lead to the correct solution.

Cohen (1994) defined cooperative learning to be when students are working together in a group small enough to allow everyone to participate. Heller et al. (1992) found that a group size of three to four students was optimal for good discussion in the group. Their observations also indicated that groups composed of two males and one female tended to be dominated by the male students. They showed that a group with a high, a medium and a low ability student performed as well as groups consisting of only high-ability students. To get well functioning groups the students were assigned rotating group roles to empower the students to take actions they would not spontaneously perform. At the end of the group discussions the students evaluated the group discussion by discussing how well they had worked together. Interview data showed that when the students were given a chance to discuss how their group functioned their attitude to group work improved. Heller et al. (1992) also designed context-rich problems which focused students' discussions on what physics concepts and principles should be applied rather than what formulas should be used.

However successful the group discussion is, there will be a point when the teacher should ask the students to present their results explicitly and to interact with the teacher (Barnes & Todd, 1995). Benckert & Pettersson (2008) showed that it is important that the teacher observes students' difficulties with the phenomenon and the physics concepts when the students try to understand the questions. The teacher should listen to students' discussions to be able to identify important questions raised in the groups that should be considered in the following lecture.

Students' alternative conceptions in mechanics

Many researchers have investigated students' understanding of concepts of physics (Hestenes, Wells, & Swackhamer, 1992; McDermott, 1984; Bayraktar, 2009). Students' commonsense beliefs have been described as misconceptions or alternative conceptions. The most common observed alternative conception related to mechanics is that students think that a force is needed to keep an object moving. As a consequence they think that it should be a force in the direction of motion (McDermott, 1984; Bayraktar, 2009).

Clement (1982) used written tests and video-taped interviews to show that many physics students have an alternative view of the relationship between force and acceleration. Many students applied the idea that continuing motion implies the presence of a continuing force in the same direction as the motion; the "motion implies force" misconception. Clement also noted that it is not likely that this misconception disappears simply because students are exposed to a physics course. The Newtonian ideas can be misperceived or distorted to fit students existing preconceptions or they may be memorized separately as formulas with little connection to the fundamental concepts. When misconceptions arise it is, according to Clement, necessary for the student to express them and to actively work out their implications.

It has also been found that students often cannot distinguish between velocity and acceleration (McDermott, 1984; Hestenes, et al., 1992). Trowbridge & McDermott (1981) found that fewer than half of the students demonstrated sufficient qualitative understanding of acceleration to be able to apply this concept in a real situation.

Aim and research questions

The main aim of this study is to investigate what problems and possibilities arise when physics teaching in Lao universities is changed to include more group discussions. We want to answer the following research questions:

How do students discuss and argue about physics during the group discussions? Do the students co-construct their answers to the questions? What difficulties with physics concepts do the students show?

What problems and possibilities regarding the changed teaching can be identified from the recorded group discussions and from interviews with teachers and students?

METHODS

Description of the context

In the beginning of the first semester 2010 the tutorials for the freshman students were organized in a somewhat different way than before. At the start of the tutorial each tutorial teacher explained some important points from the last lesson and then the teacher solved some example problems. After that the teacher told the students that they should answer some questions in small groups. The first author explained the purpose of the research and the procedure for the rest of the tutorial. She advised the students to set up groups with three to four students in each. The teacher and the first author distributed the questions to the groups (two questions per group). The students had about ten minutes to discuss these two questions.

When the group discussion session was ended the teacher told the students to give their answers to the teacher, who wrote the students' answers on the blackboard. The written answers were then given back to each group. One student from each group presented the reasons why they had chosen their answer while the other students listened. After that the teacher explained which answer was correct and why.

Data collection

Three multiple choice questions were selected for the group discussions. These three questions were taken from the book *Peer Instruction: A user's Manual* by Mazur (1997) and are shown in the appendix. These questions were chosen because we found that Laotian students had problems with the concepts of mechanics, when they were tested by the Force Concept Inventory. Therefore the students got qualitative questions about mechanics concepts to discuss in the group discussions.

Seven classes participated in this study. Each class consisted of 7-11 groups with three to four students in each group. There were in total 64 groups in the seven classes that discussed two questions out of the three selected. There were 52 groups that discussed question 1, 37 groups discussed question 2 and 39 groups discussed question 3. In each class the first author asked the students which group that wanted to be recorded. One group per class was recorded during their discussion. About 10 minutes of discussion was recorded from the group and then about 10 minutes when a student from each group explained their answers, and finally, about 10 minutes when the teacher explained and showed the correct answer.

After the activity described above the first author asked which students wanted to be interviewed. There were fourteen volunteer students who were interviewed. Each interview took about 10 to 20 minutes per student. The semi-structured interview was based on the following questions:

- ✓ *What do you think about the questions you answered this time?*
- ✓ *Which question led to interesting discussions in your group? Why?*
- ✓ *Do you have some comments about group work in the tutorial session?*
- ✓ *What did you learn from the group discussion?*
- ✓ *What did you learn from the discussion in class and the teacher's explanations?*

Semi-structured interviews were also held with three teachers. The teachers answered the following three questions:

- ✓ *What do you think about the qualitative questions the students answered this time?*
- ✓ *Do you have some comments about group work in the tutorial session?*
- ✓ *How did you experience the summing up discussion after the group work?*

Analysis

The first author looked through the video tape of the group discussions and noted what happened. Next, she looked through the tape several times, and transcribed everything from the recording in Lao language. A great deal of the transcribed group discussions were then translated to English to be possible to read and analyze also for the second author.

In the video recorded group discussions we first noted if the students articulated their views, that is, if they verbalised their intuitive ideas and interpretations. Then we looked for situations when the students disagreed with each other when they tried to answer the questions, and if they then had to clarify their positions to resolve the conflict. After that, we checked if the students listened to each other and to what degree they co-constructed the shared knowledge. We also looked at what problems the students had with interpreting physics concepts and what alternative concepts they used in the discussion.

The first author also transcribed the video recorded interviews with the teachers and the students in Lao language. About half of these interviews were then translated to English. In the transcribed interviews with the teachers we looked for the teachers' observations of how the group discussions functioned, and for the possibilities they saw with this teaching method. In the interviews with the students we focused on the students' opinions about solving problems in groups, what they thought about the questions, and what experiences they got during the discussions. We then identified the problems and possibilities with group discussions that were mentioned during the interviews.

RESULTS

Group discussions

Seven groups were recorded when they discussed and tried to answer two qualitative questions each. Five of the groups answered question 1, five groups answered question 2, and 4 groups answered question 3. Here we describe the discussion and the collaboration in some of the groups. We do especially look at how well the students articulate their views, if they disagree and if all students in the group participate in co-constructing the answer. We also comment on the difficulties that the students have with the mechanic concepts.

Two groups discussing question 1

Problem one was the easiest question to answer for the students. Of all the groups that answered this question 71% chose the correct answer. Four of the five recorded groups chose the correct answer. The problem is about a ball that is thrown down from the top of a tower and the students are asked for the acceleration of the ball after it has been released. The complete question is shown in the appendix. Below we show parts of the discussion in two groups. One of these groups co-construct the correct answer and the other choose the wrong answer without co-construction.

The first example shows the discussion in a group that consisted of four students, one female (St4) and three males (St1, St2, and St3). The students read the question and tried to understand it. The discussion started.

St1: During this object moves down, its acceleration must be larger than zero, and it has constant value.

St2: Do you mean that the acceleration of this object is gravitational acceleration?

St1: That's right.

St4: Yes, I think so. Falling of an object from high to low level is the free fall; therefore its acceleration must be gravitational acceleration. Therefore the correct answer should be B. What do you think St1?

The discussion went on and the students often referred to what they had learned about free fall. The students also asked for the others' point of views.

St4: What do you think St2 and St3? If you agree with my idea, we should think about how to explain it.

In this group the students articulated their views rather well. They asked each other about the others' opinions and they co-constructed the answer and all of them seemed to agree on the answer at the end of the discussion. They did not have conflicting views during the discussion so there was no debate about different ideas.

In another group, that consisted of four women (St5, St6, St7, and St8), the students had conflicting ideas about the acceleration of the ball. One of the students (St5) started the discussion by stating that the acceleration is g and she asked what the full name of g is.

St7: OK! The name of g is gravitational acceleration. Therefore, when this ball is moving down its acceleration must be g which is gravitational acceleration.

St5: I think so. So the correct answer should be B, or what do you think?

St6: No, I don't think so. Its acceleration should be larger than g because during this object is mowing it has acceleration inside the object. When this object moves in the air it will, in addition, be exerted by gravitational acceleration. So the total acceleration must be larger than g and the correct answer should be A.

Student 6 was very decisive about her idea. At least one of the other students doubted that this was the correct answer, but she could not explain why her idea was the correct one.

All the students in the group tried to verbalize their ideas, but it was only student 6 that articulated her idea clearly. The other students had other ideas but they could not explain them and student 6 did not seem to listen to them. These students did not co-construct the answer together. The students in this group just accepted the suggested answer from student 6 which, however, turned out to not be correct.

Two groups discussing question 2

Question 2 is about a ball that is thrown up in the air and the students are asked about the velocity and acceleration at the highest point. Of all the groups that answered this question 51% chose the correct answer, and two of the five recorded groups chose the correct answer. Below we show parts of the discussion in two groups. In one of these groups three students co-construct the correct answer while the fourth student is indifferent. In the second group the students chose the wrong answer without co-construction.

We first describe a group with four male students (St9, St10, St11, and St12) who discussed question 2. The students read the textbook and one of the students said that it was about projectile motion, but he could not understand about the x-axis and y-axis, because the ball just moved up and down. He suggested that both v_x and v_y should be zero at the highest point. The other students agreed and they went on to discuss if the acceleration also should be zero. Two of the students suggested that it should be so and another student was unsure. The fourth student in the group went on discussing projectile motion:

St12:Yes, I agree, this object's movement is projectile motion, so the velocity at the highest point must be equal to zero, but its acceleration is not equal to zero, because its acceleration is gravitational acceleration, and it is never equal to zero. Therefore the correct answer should be C answer.

St10:No, I don't think so. Why isn't the acceleration equal to zero? If it is not equal to zero this object will continue to move. I think that both of them are equal to zero.

St12:No, impossible! At the highest point the acceleration is not equal to zero, because it is gravitational acceleration, and g is never equal to zero. Therefore the correct answer must be C answer.

St9: If we choose alternative C, what information will we use to explain? And who will present?

St12:We should explain that the motion of this object is projectile motion. During the object moves in the air this object will have acceleration which is gravitational acceleration. At the highest point it will only be the velocity that is equal to zero, but acceleration is never equal to zero.

St11:I agree with you. And you?

St9: Ho! Sure 100 percent agree. How about you St10?

St10:I don't know, I have no idea, but I can follow you.

The students disagree and have to articulate and clarify their ideas during the discussion. Three of the four students agree to the idea put forward by student 12. They co-construct the correct answer. One of the students does not have any idea, but he does not oppose to the suggested solution. He would need more explanations from the other students to understand why the C-alternative is correct, but they do not continue discussing with him.

In another group that consisted of four men (St13, St14, St15, and St16), they also discussed question 2. Two of the students (St13 and St14) started to explain their idea that both the velocity and acceleration must be zero at the highest point. Student 16 also agreed to their ideas, but student 15 had another opinion.

St15:Wait wait, I don't agree with your ideas, I think that it is only the value of velocity that is equal to zero but the acceleration is not equal to zero, and the alternative C is the correct answer, I think. Now, I am trying to find information for an explanation.

However, while student 15 tried to find an explanation to his idea, students 13 and 16 went on to the next question. Student 14 still tried to formulate an explanation why they chose alternative A.

St14:I think that we should say: The magnitudes of velocity and acceleration at the highest point are equal to zero. So the correct answer must be alternative A. Do you agree with me?

Student 15 did not say anything more about the choice of answer. He thought that the C answer was correct, but the other students did not listen to him or help him to motivate his idea. Finally, they decided to choose the wrong answer. Students in this group articulated their ideas but they did not help each other to co-construct the answer.

Questions 1 and 2 both deal with free fall. That it is about free fall is more evident in the first question and it is then easy for the students to associate to the description of free fall in the textbook. Question 2 was more difficult for the students. Many of the students showed that they could not differentiate between velocity and acceleration. They thought that both velocity and acceleration should be zero at the highest point. Some of the students also argued that there must be an inner acceleration in the ball, so that the acceleration of the ball should be greater than g.

Two groups discussing question 3

Question 3 is about a person who pulls a block across a rough surface at constant speed. The question is about relations between the magnitudes of the given forces. The question is shown in the appendix. Question 3 was a difficult question for the students. Of all the groups answering this question 54% chose the correct answer. Three of the four recorded groups chose the wrong answer. Below we show parts of the discussion in two groups. In one of these groups three students co-construct the correct answer. In the second group the students chose the wrong answer.

The first group to solve this problem consisted of four students, one female (St20) and three males (St17, St18, and St19). During the students in this group discussed together they put the symbol of each force into the picture. One student in this group had problem with the k symbol. Another student then said that usually k was a constant, but in this question he did not know which force k represented. One of the students then advised his friends to read the question again. After that, they continued to discuss.

St20:Are you sure? k is friction force, but the symbol of friction force in the physics textbook is f.

St18:Yes, I'm very sure and the magnitude of the force which is the forward force must be bigger than the magnitude of friction force, so this object can move forward.

Student 18 started to talk about component forces, he said:

St18:F-force is the pulling force, so the magnitude of the F-force must be bigger than the friction force.

When he talked, he drew the components of the force F along the x and y axis (see Figure 1). Student 17 ignored this, and said:

St17:The magnitudes of reaction force and weight must be equal, and we should put each force to this object and I think the alternative C is correct."

St18:No, I don't think so. It is not true P will be equal to N. I think that P must be bigger than N. If we look at the picture, the Y axis has two forces including the reaction force which has the opposite direction to the weight. So P must be bigger than N, and F is also bigger than k, sure. Therefore the correct answer must be alternative C.

St20:Ok, I agree with you.

Student 17 said that the magnitude of reaction force and weight must be equal, but he decided to choose answer C although the information he gave was not related to the C answer. In this group there were only two students who articulated their views, and they also co-constructed the correct answer, while one student did not at all participate in their discussions.

In another group the students discussed the same question. This group consisted of four men (St13, St14, St15 and St16). Three students in this group read the question, while one student read the physics textbook. They discussed about arrows in the picture, and they also put a symbol to each arrow. Student 15 was confused about the symbol of friction force, k. He claimed that the friction symbol of the friction force must be f, while the first student (St13) said that it was not necessary. The important thing was that they understood the meaning of it. Student 15 explained that this object moves from left to right, so the force on the left hand side should be friction force. He continued to explain that the forces along the y axis are weight and the reaction force, and these forces must be equal, but in different directions. So the correct answer should be A alternative. Student 13 had a different idea, he said:

St13:Wait! wait, I think, before we decide to choose the answer, we should read the question again and also read the lesson about force. This question talks about an object moving on the surface, I guess this question must relate to our lesson.

St16:I think my idea is correct, because this object must be exerted by four forces, and the magnitude of force which is in the same direction as the object is moving must be equal to the friction force, and weight must be equal to the reaction force.

St13:I don't think so. I think that, if the magnitudes of force F and friction force are equal this object could not move forward, sure. I am sure; the force F must be bigger than friction force. For the weight and reaction force, I am not sure.

St14:I think that, weight and reaction force are of the same size, but has different directions, and I also think that, F must be bigger than the friction force. As the alternative answers don't have this case, I guess the suitable answer should be C alternative.

St16:Why do you select C, why don't you select E?

St14:I don't know. One thing I see in the C answer is that the force F is bigger than k.

St15:I agree with St14's idea about the C answer, but I don't have any explanation. I have problem with the direction of force F, why is it not in the direction of X axis or Y axis? And what does it mean?

Nobody gave any explanation to him, but student 16 had another idea, he said:

St16:OK! The suitable way, should we choose E answer? Are you OK?

St14:OK! I agree with you.

The other two students (St13 and St15) did not make any comments while the students 14 and 16 decided to choose the E answer, which is a wrong answer.

In this group, all students articulated their ideas, but they could not use and did not mention the concept of component forces. The students started to co-construct an answer. They all shared their ideas with each other and made comments to the others ideas. However, the process of co-construction stopped when the students could not give arguments for their ideas. Students 14 and 15 wanted to select the C answer (correct answer) but they could not explain why the reaction force should be smaller than the weight. Student 16 was like a leader of the group and suggested that they should select the E alternative. One student agreed with him but the other two students did not say anything about this suggestion.

From the discussion of the four recorded groups, we saw that most students thought that the force "F" must be bigger than the friction force "k or f", but for the weight "P" and the normal force "N" many students in different groups thought that the two forces must be equal but with different directions. Therefore three groups decided to choose the E alternative. Only one group selected the correct answer. In this group, there was only one student that had correct ideas. When he explained to his friends, he drew a picture, and focused on why P must be bigger than N at the same time. From the recorded groups we saw that three students in two groups suspected that the C alternative was more suitable than the E alternative, but they could not explain why the weight should be bigger than the normal force.

To be able to answer this question, the students had to observe that the acceleration is equal to zero. According to Newton's second law this tells us that the net force on this object should be equal to zero. However, most students, who answered this question, forgot the information about constant speed; only one group discussed constant speed. They said that the meaning of constant speed is that the velocity does not change during the object is moving, but they could not apply this information when they answered the question.

How do students discuss about physics during the group discussion?

The group discussions showed that it was difficult for many of the students to differentiate between velocity and acceleration. In the first question it was quite clear for the students that it was about free fall and they referred to the textbook when they discussed this question and easily come to the answer "g", the gravitational acceleration. The second question was also about free fall, but in this question the students were asked about the velocity and acceleration at the highest point. In this question it was not as easy for the students as in the first question to associate to free fall. Many of the students showed in the discussion that they did not really understand what acceleration is. The third question showed that many of the students had problems with a force that was not in the direction of motion. They did not know how to decompose it into components. Most of the students did not either consider the fact that the velocity was constant so that the resulting force should be zero. Many of the students wanted a force in the direction of motion.

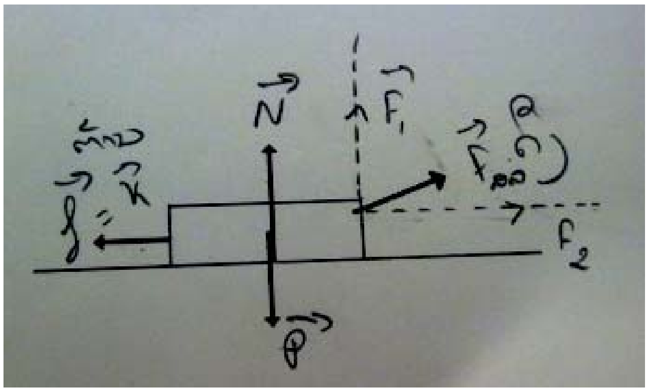

Figure 1. A student's drawing to explain to his friends

We found that the students tried to talk and share their ideas with each other in the group discussions and most of them articulated their views. In almost all of the groups some of the group members co-constructed the answer. A few students, though, did not say anything when their friends chose the answer, they just nodded. In nearly all the groups the students had conflicting ideas but the discussions resulted in wrong answers about as many times as in correct answers. In one of the fourteen groups the students had conflicting ideas that they could not resolve and they voted about the answer.

Presenting and discussing answers and explanations in class

When a group discussion session was ended the teacher told the students to write the answer on a piece of paper and give it to the teacher. The teacher wrote the students' answers on the blackboard. The written answers were then given back to each group. One student from each group presented the reasons why they had chosen their answer. After that the teacher gave the correct answers and explained why it was correct.

After students' answers had been written on the blackboard, the first author observed that some of the students felt excited when they saw that other groups had chosen the same answer while other students got a bit worried about their answers and explanations since they had chosen a different answer than the other groups. In one class, one student got very worried when he saw that the presentations of the first three groups were different from his ideas. He had to ask a teacher who stood quite close to his group, and they started a discussion that disturbed the fourth presenter.

We also observed that the students differed in self confidence and style of presenting. Some students had self confidence when they explained and used their hands to show the movements of the objects, while other students just talked and did not show any action when they explained. There were also two students in different classes that went to the whiteboard when they presented the forces acting on the object (question 3), drew a picture and wrote the symbols of the forces on x axis and on y axis. In a few classes the teacher asked the students if they wanted to add some more ideas after each group had presented their answers and arguments. Many ideas then came up, especially about question 3. Many students thought that the normal force and the weight had the same magnitude.

In one class, after the teacher had written the students' answers on the whiteboard, students in some groups who had chosen the same answer, started to help each other to explain. There were three groups that had selected the same answers and when the first of these groups had finished their presentation the other two groups continued to add some ideas that the first group had not referred to.

Teachers' and Students' views of group discussion

Teachers' views

The three interviewed teachers all said that the students through the group discussions had a good chance to show their ideas and to exchange ideas with their friends. One of the teachers explained that in class some students are not self confident enough and don't answer, when the teacher asks, but during the group discussions all students must think and talk about their ideas and group work is therefore a good way to improve students' learning. One of the teachers said that individual problem solving is suitable for good and middle students because they have self confidence, but group discussions are suitable for all students because the good students will help their friends. One teacher remarked that the group discussion reduced students' stress when they found difficult problems. The teachers also observed that some students had a lot to discuss when they saw the different answers during the summing up discussion.

One teacher said that group work was a new method for her. She had heard about group work, but she had only vague ideas about it. Now she had got good experience about it and she wanted her students to solve problems in small groups in the tutorial session, but it should not necessarily be every week, rather once a month or two or three times per semester.

One of the teachers had also noted that the students used the textbook to find information to answer the questions. She found that the students read the textbook carefully and tried to understand the meaning of free fall and forces. This was quite different from the occasions when the students solved quantitative problems, she said. Then they just read the definition and looked for equations to use in the calculations. She also wanted the students to discuss more than two qualitative questions each tutorial. Another teacher on the other hand said that 90 minutes was a rather short time for the tutorial, if the students should have time for both discussing qualitative questions and end-of-chapter questions in groups.

Students' views

All the interviewed students found the group discussions to be a good teaching method, because they then had a good chance to share ideas with each other. One student referred to the Lao proverb *"Many hands make a light work"*. It means that the more people, the easier the job will be. One of the students said that group discussion is a good thing because the students then can exchange ideas with their friends in the group and then they can help each other to analyze these ideas and select what should be explained in class. Another student pointed out that when the students share ideas together they get many more ideas than with individual problem solving. Yet another student remarked that it was interesting that it was not boring to solve problems together in the group.

One student said that in the group discussion in the tutorial the students learned to think, talk and share ideas, which was not true when the students set up groups by themselves outside class. The students then just listen to and look at the solution of a good student. A female student described her experience about solving problems in group when she studied in high school:

I solved mathematical problems in groups, but it was different from this time, because at that time the members of the group were about 10-12 students per group and the group had a leader. Some students helped each other to solve the problems, while others just listened and solved the problems by themselves. This time the number of group members was smaller and each person had to show their idea to the friends in the group and they had to help each other to choose the answer and explanation.

One of the students said that it was good to work in groups because almost all the students could help each other, but he also pointed out that it was important to pay attention to the other students' feelings when they discussed together. One student said that he was worried that other students would not accept his idea. They should not ignore comments from some students, when they selected the answer to a question.

Many of the students said that the group size of 3-4 students was good and that it was important to have a mixture of good, middle and weak students in each group so that the students could help each other in the group. Some of the students also pointed out that they found the time for the group discussion too short.

Some students made a comparison between qualitative and quantitative questions. They said that the qualitative questions were interesting questions because the phenomena of these questions were related to their daily life, and also related to their lessons about free fall, projectile motion and forces. Other students also said that it was good if they discussed these matters before they solved quantitative problems because they could use knowledge from discussions when they solved end-of-chapter problems. Some of the students explained that there are many ways to explain the answer to a qualitative question and they could find the information from many sources to explain such as teacher, physics textbook, experiment and friends in the group, therefore, it was suitable to discuss these questions in group. For the quantitative problem, the answer is number, which gave them self-confidence because they could compare their answer with the answer in the textbook. This is not possible with the qualitative questions where the students also had to explain for the rest of the class why they had chosen a special answer.

The students were also asked what they learned from the discussion in class and from the teacher's explanation. Many students answered that they became confused when they heard the students in the other groups explain their answers and ideas. There were many different answers and ideas. When the teacher showed the correct answers and explained it, they got an improved understanding about free fall and component forces.

Problems and possibilities with the changed teaching

Both teachers and students found group discussions to be a good method, because the students have a good chance to exchange their ideas with their friends and with the teacher. The students seemed to enjoy the group discussions. One student referred to one Lao proverb *"Many hands make a light work"*. Many students commented that when they first had discussed in groups and then saw many different answers on the whiteboard they got confused, but when the teacher then explained they understood. The teachers found group work to be a good way to improve students' learning. Many students found the group size of 3-4 students adequate and they said that it was important to have a mixture of good, middle and weak students, because the good students could then help their friends.

The students said that the qualitative questions were suitable to discuss in group because they could find information from different sources such as; teacher, experiment, textbook, and their friends in the group. One teacher observed that the students read the textbook more carefully when they looked for answers to the qualitative questions than when they solved end-of-chapter questions. Many students explained that the discussions of the qualitative questions helped them to solve the quantitative questions.

The recorded group discussions showed that many of the students had problems with physics concepts, and they needed to discuss to get a grip on the concepts. Some of them could not discriminate between velocity and acceleration and a few thought that objects had an inner acceleration.

The recorded group discussions also showed that when the students did not listen to each other, this lead to an unsuccessful group discussion, with no co-construction of the answer. Most students liked group discussions, but a few students were worried to tell their ideas to friends in their group and in class. On the other hand, one teacher said that group discussions reduced students' stress when they encountered difficult problems. Several students said that they were confused during the discussion in class, when different ideas were presented, but claimed that they got a clear understanding after the teacher's explanations.

The students found the time for discussion too short and a teacher said that longer time for the tutorial is needed if students should discuss both qualitative questions and end-of-chapter problems. Another teacher commented that group discussions were good but it should not necessarily be every week.

DISCUSSION AND CONCLUSIONS

Most of our students were actively engaged in the group discussions, even if some of the groups had two or three students who were more active than the others, and in one group we observed that one student did not participate in the discussion at all. All the interviewed students also found the group discussions to be a good teaching method, because they had a good chance to share ideas with each other and in this way they got much more ideas than with individual problem solving. However, the group discussions did show that many of the students did not come to an understanding of the actual physical concepts through the discussions.

Many of the students did not fully understand the concepts of velocity and acceleration. For example, in several groups the students thought that, when a ball is thrown up in the air, both velocity and acceleration must be zero at the highest point. It is well-known that students often cannot distinguish between velocity and acceleration (McDermott, 1984; Hestenes et al., 1992). In a study at a university in USA, Trowbridge and McDermott (1981) found that fewer than half of students demonstrated sufficient qualitative understanding of acceleration to be able to apply this concept in a real situation. The third of our questions, in which a person pulls a block across a rough surface with constant speed, was the most difficult for the students. They did not know how to decompose the force into its components and most of them did not discuss the importance of the constant velocity. To be able to arrive at a correct solution to this problem, they should have needed a lot more time for discussion. Some students, however, said that they clearly understood the answer after the teacher's explanation. Even though the discussions in the groups did not always lead to a correct answer, it made the students focus on the same problem, so that all of them could follow the discussion in the whole class and relate their own ideas to the teacher's explanations.

Tao (1999) found that co-construction may lead to the correct as well as the wrong solution, but discussion involving conflicting ideas nearly always lead to the correct solution. However, in our case, conflicting ideas in some groups led to the wrong answer. Moreover, in one group conflicting ideas resulted in voting about the answer. These different results could depend on differences between these studies. Tao (1999) studied collaboration between students working in pairs while in this study there were three or four students in each group. In a dyad the two different opinions start on an equal footing since there is one person advocating each standpoint whereas in larger groups the correct viewpoint might be held by only one of the students. It would require a lot of self-confidence and skill in argumentation of this single student to convince the others to change opinion. The students in our study have little training in argumentation and since physics is seen as a difficult subject many students have bad self-confidence in solving physics problems.

An important point is the time for discussion. Tao's students had 75 minutes to discuss five problems, but in this study, the students had 10 minutes to discuss two questions. It is probable that our students did not have enough time to resolve conflicting ideas. The video recorded group discussions show that the students felt stressed to finish the discussion in the assigned time and several discussions did not come to a consensus before the students had to move on to the next task. This is also confirmed by students' remarks in interviews that it was too short time for the discussions. We agree with Tao that conflicting views can be a good starting point for a discussion, but students need enough time to resolve all conflicting ideas.

Some of the students were more active than the others in the group discussions and sometimes the students did not listen to each others' arguments. These are signs that all groups did not function as well as they should. The students need to be taught about working in groups, for example that they should listen to each other and make sure that all students in the group agree on all the steps in the solution. It could probably be possible to get better functioning groups by following the advice from Heller and Hollabaugh (1992) and let the students evaluate the group discussions and to introduce group roles.

The three interviewed teachers were in general positive to use group discussions in their teaching but they had somewhat different opinions about how often it should be used. One teacher commented that the group discussions should not necessarily be every week, perhaps only two or three times per semester. A comment from another teacher give information on the frame factors the teaching has to adjust to. She said that 90 minutes for the tutorials is too short time to include group discussions around both extra qualitative questions and the usual end-of-chapter problems. The teachers see the benefit of using group discussions with qualitative questions but they are at the same time expected to cover all the end-of-chapter problems. A successful introduction of group discussions requires that the teachers discuss how much time that should be devoted to group discussions and how much time should be used for qualitative questions and end-of-chapter questions problems, respectively. The teachers also need to learn about methods to get better functioning group discussions.

Both teachers and students were interested in this teaching method and the students wanted their teachers to set up groups again when they solved physics problems in class. This is a good starting point for future work with this method. We would though recommend more time for the discussions, and that the students should be taught about working in groups to improve the result of the discussions. We are also convinced that following up of the group work with teacher explanations and teacher and student discussions is essential for a good learning outcome. If these circumstances are taken care of, the group discussions seem to have prospect to give good learning possibilities for the students.

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Appendix

1. A ball is thrown downward (not dropped) from the top of a tower. After being released, its downward acceleration will be
   - A greater than g.
   - B exactly g.
   - C smaller than g.

2. You are throwing a ball straight up in the air. At the highest point, the ball's
   - A velocity and acceleration are zero.
   - B velocity is nonzero but its acceleration is zero.
   - C acceleration is nonzero, but its velocity is zero.
   - D velocity and acceleration are both nonzero.

3. A person pulls a block across a rough horizontal surface at a constant speed by applying a force F. The arrows in the diagram below correctly indicate the directions, but not necessarily the magnitudes of the various forces on the block. Which of the following relations among the magnitudes W, k, N, and F must be true?

A F=k and N=W
B F=k and N>W
C F>k and N<W
D F<k and N=W
E None of the above choices.