The influence of problem solving strategies and cooperative learning on teachers’ ability to solve physics problems
Jeanne Kriek & Diane Grayson
Cimste, Unisa
South Africa
kriekj@unisa.ac.za

Introduction
Although problem-solving is central to any Physics course, students often find it very difficult. If students find it difficult, what about the teachers? We suspected that the teachers’ problem solving skills needed improvement but we wanted confirmation. Our suspicion was confirmed when a pre-test (comprising Physics problems taken from TIMSS questions for Grade 12 learners) was given to 18 teachers currently teaching Grade 12 Physics. The average mark was 24%.

Since research has shown that teaching problem solving through cooperative learning in Physics courses can improve students’ problem-solving skills (Heller et al, 1992), we decided to use the approach with a group of teachers currently teaching Physical Science and enrolled for the UNISA Physics for Teachers module.

A three-hour workshop was run with 5 teachers who, between them, teach 14 Physical Science classes comprising 412 learners. In the workshop we explained a problem solving strategy and cooperative learning principles to the teachers. We were interested in seeing if this teaching approach would have any effect on the teachers’ and their learners’ ability to solve Physics problems. The teachers were given evaluation forms at the end of the workshop to determine their perception of the effect of the workshop. In addition, they were given feedback forms on which they were asked to give feedback on the implementation of cooperative learning and problem solving strategy in their classrooms. The feedback forms were handed in at the following workshop.

Theoretical Context
Cooperative Learning
According to Johnson, DW, Johnson RT and Holubec, EJ (1994), studies conducted over the past 90 years show that cooperative learning strategies are superior to competitive or individualistic strategies in promoting:

- student achievement
  including more higher-level reasoning, more frequent creation of new ideas and solutions, greater transfer of learnings from one context to another, improved metacognitive strategies

- positive interpersonal interactions
  lead to commitment to educational goals and to other students, acceptance of personal responsibility, motivation, satisfaction, improved morale, greater tolerance in culturally diverse groups

- social support
  promotes productivity, physical and psychological health, ability to cope with stress

- self-esteem
  such as increased sense of their own worth and capabilities, valuing of their contributions to the group’s success

Furthermore, results show that low and medium-ability students especially benefit from working collaboratively with peers from the full range of abilities. But there is also evidence that high-ability students are better off academically when they collaborate with medium- and low-ability peers than when they work alone. (Johnson, Johnson, Roy & Zaidman, 1986).

Johnson et al (1994) indicate that cooperative learning is about students working together to accomplish shared goals, individuals seeking outcomes that benefit themselves and all other group members and using small groups to enable students to maximize both their own and their peer’s learning. Cooperative learning is not competitive or individualistic. It is not a seating arrangement, where students sit in groups but are taught from the front of the room.
It is also not one person working and others freeloading. Furthermore, group work is not necessarily cooperative. In group work various problems may arise, such as:

- More able students may take the lead, thus benefit more
- Some students may go along for a free ride
- May get a dysfunctional distribution of labour (e.g. I’m the thinker, you’re the scribe)
- Unwillingness of some to take or share responsibility
- Destructive conflict
- Avoiding the task

For cooperative learning to be successful, Johnson et al (1994) indicate there are five requirements, namely,

1. **Positive interdependence**
   The success of one person depends on the success of the others. Students must both: (i) learn the material and (ii) ensure all group members learn it. No freeloaders are allowed, everyone must contribute.

2. **Face-to-face interaction**
   Students facilitate each other’s success.

3. **Individual accountability and personal responsibility to achieve group’s goals**
   Students learn together but perform alone. The group holds each person responsible for contributing their fair share to the group’s success. Each person’s contribution should be assessed. Feedback should be given to individuals and the group.

4. **Interpersonal and small-group skills**
   Students must get to know and trust each other, communicate accurately, accept and support one another and resolve conflicts constructively. Students need to be taught group skills and motivated to use them.

5. **Group processing**
   The effectiveness of group work is influenced by whether groups reflect on how well they function. Time needs to be allocated for group processing.

In terms of improving problem-solving skills in Physics, Heller & Hollabaugh (1994) and Heller et al (1994) have shown that combining the use of a problem-solving strategy with cooperative learning leads to improved student performance in problem-solving activities.

**Method**

Three workshops were run during the year in the Limpopo province for the teachers enrolled for the module Physics for Teachers, currently presented by distance mode by Unisa. The teachers teach at rural schools and the area is very remote, which compounds the problem of isolation experienced by distance education students in general. For the workshop described in this paper, 5 of the 6 Physics teachers attended.

At the beginning of the workshop the teachers were given a pre-test consisting of one Grade 12 level Physics problem in order to test their problem solving skills, and one question on cooperative learning in order to find out what they know about it. The test problem was a typical work and energy problem (see Figure 1). The workshop was scheduled for 3 hours, so time was very limited.

**Test problem:**

1. A pendulum of length L in the figure is released from point A. As it swings down, the string strikes the peg at B, and the ball swings through C. How fast is the ball moving as it passes through C? (Express your answer in terms of L).

2. What does the term cooperative learning mean to you?

**Problem solving strategy**

![Figure 1: Pretest question given to teachers](image-url)
The problem-solving strategy we introduced emphasizes the analysis of the problem situation, planning a solution before the mathematical manipulation of equations, and checking and evaluating the answer to see if it makes sense. We provided the teachers with a detailed problem solving strategy with specified steps (Grayson, 1996) and applied it to a typical work-energy problem. The strategy consists of the following steps:

1. Draw a sketch of the situation
2. List all the givens
3. Decide what is required
4. Solve for what is required
5. Interpret your answer

Cooperative Learning
We then introduced the concept of cooperative learning and explained the benefits of using this approach. Cooperative learning was compared with group work, indicating the differences between the two. We then discussed the role of the teacher in cooperative learning, which include:

- To specify the lesson objectives, both academic and social skills
- To select the groups, the students’ roles within the groups, arrange the room, prepare the necessary materials
- To explain the task, including the academic task, the criteria for success and desired behaviours (e.g. take turns, stay with your group)
- To set the cooperative lesson in motion, which may or may not involve a particular structure
- To monitor the effectiveness of the groups and intervene where necessary, e.g. to clarify instructions, review important procedures, answer questions, teach tasks skills, teach social skills.
- To evaluate students’ achievements, e.g. by summarizing main points, taking in work to be marked
- To help students discuss with each other how well they are collaborating, e.g. asking for feedback on group processes

We also discussed some effective group behaviors to be encouraged such as:

- Have each member explain how to get the answer
- Ask each member to relate what is being learned to previous learning
- Check to make sure everyone in the group understands the material and agrees with the answers
- Encourage everyone to participate
- Listen accurately to what other group members are saying
- Not change their minds unless they are logically persuaded (majority rule does not promote learning)
- Critique ideas, not people

Different roles that could be assigned to different members of a group were also discussed. For the purposes of the workshop, we chose the roles of explainer, who describes how to complete the task, and gives feedback on others’ work, the recorder who accurately records the group’s findings and answers as well as the direction giver who reviews instructions and calls attention to time limits. Another nine roles were discussed but not assigned because of the time factor.

Because the teachers feel very isolated we tried to address this problem by dividing the teachers into two groups, one group of two teachers and the other group consisting of three, according to where they live. We assigned the roles discussed previously to each individual in the group and changed the roles with each problem so that they could experience different roles.

During the next part of the workshop the teachers were given three problems on work and energy, the topic of the workshop. Instead of explaining the content at the beginning of the workshop, explanation of the content was only given when the teachers experienced difficulties. Because of the time limit, the teachers could not report back.

At the end of the workshop we gave them a post test which was the same as the pre-test.

After the test, the teachers were asked to fill in an evaluation form. We also wanted to encourage the teachers to implement cooperative learning and the problem solving strategy in their classrooms. We thus gave them a feedback form to be handed in at the following workshop.
Results
Pre-and post test
The teachers found the problem in the pretest very difficult. This was reflected in the test average, which was 30%. However, there was an improvement from pretest to posttest, with the average of the posttest being 50%. Unfortunately one teacher came late and his results could not be included in the pre-test. All the other teachers improved their marks, except for one teacher whose marks stayed the same.

Although none of the teachers were able to obtain full marks on the pretest or posttest, when analyzing the pre-test only two teachers gave the physics principle they were going to use to solve the problem, while in the post test all of the teachers included the principle, in other words used aspects of a problem solving strategy. In the second question two teachers knew what cooperative learning meant in the pre-test, while in the post-test all the teachers knew.

Evaluation forms
In response to the question: “In what ways did you benefit from being part of a cooperative group today?” the following responses were obtained to the question:

- I have benefit[ed] a lot as I realized there is something I need to understand better.
- We were sharing ideas to such an extent that where I had misconception I was corrected.
- I could understand better than when I am alone
- I learnt to share ideas with my fellows. The more we work together, the more I understand.

In response to the question: “What do you think are the most important features of a well functioning cooperative learning group?” the responses were the following:

- Sharing ideas, encouraging those who are passive during discussions
- All people have to participate
- Each member contribute[s] in the problem solving. Each member benefit[s] from it.
- Supporting one another and also listening as the other one explains something.

In response to the question: “Do you feel that working in a cooperative learning group today has had an effect on your (a) confidence?” the responses were:

- Yes, because [from] today onwards I will have more confidence on facing the students with more information
- Yes, but it does not discourage me, it made me gain more confidence
- Yes, because concepts which we have misunderstood can be corrected during cooperative learning
- Yes, our ideas towards solving the problem together made me feel like forming part of finding solution
- Yes, it boosted my self-esteem and my confidence also

(b) “ability to solve physics problems?”
- Yes, because today I got more skills than before
- Yes, it made me improve my ability
- Yes, because we share ideas which at the end help us to solve the problem
- One comes with what the other could not and together we solve it
- My scope was widened and I can now look at problems from different angles

In response to the question: “What do you think of the problems solving strategy that you learnt today?” the responses were:

- Problem strategy were quite good!!
- It is a good strategy and it help a lot
- We have to apply these in our classroom situation so that students who are performing very poor may improve
- Much complicated and tricky. Much helpful though needs more practice
- It is very helpful and will make me to explain problems to my pupils efficiently.

Feedback forms
Questions were asked to find out to what extent the teachers actually did implement cooperative learning and problem solving strategies in their classrooms. Unfortunately the teachers did not bring along the feedback forms so the questions were asked verbally.

In response to the question: "What do you think the difference is between group work and cooperative learning?" the responses were:

“Group work: only 1 or 2 people work, the others don’t while in cooperative learning everyone has to contribute, not passive learners.”

In response to the question: "Under what circumstances is it appropriate to use cooperative learning?" the response was:

“When the learners have to discover for themselves or when doing revision”

In response to the question: “Approximately how many times were you able to use cooperative strategies with your learners?” the answer was “several times”

In response to the question: “In what way did your learners benefit from using cooperative learning?” the responses were:

“The learners enjoyed it, it gave them time to talk which they like very much. There was an improvement in their performance. Learners are sometimes afraid to ask teachers, but not their peers. The learners discover for themselves, and then it is not easy to forget typical when doing practical work. They enjoyed solving problems in Physics when assigned to cooperative learning groups”

When asked if they will use this method again? All replied in a chorus “very often”

**Limitations**

One limitation of this study is the small number of teachers. Nonetheless, the improvement in teachers’ problem-solving ability is significant even with this small number. We would like to use the same approach on more teachers.

Another limitation is that we would have liked to give the teachers the same test after a few months to see what the effect was. Unfortunately we will not be able to see the same teachers again, but we will keep it in mind when we use the same approach again.

**Implications**

Although we were working with a small number of teachers this study shows that teaching problem solving strategies explicitly, together with cooperative learning principles, has a positive effect on teachers’ ability to solve physics problems.

Because teachers are confronted with big classes, cooperative learning has the potential, if shown to be effective, to be a valuable teaching approach. It could improve the quality of learning. One teacher is confronted with many learners and this could be of value.

Further research is needed to see if these strategies will improve learners’ problem solving abilities.

Cooperative learning is also a useful tool for teacher professional development. Furthermore, since teachers often feel isolated this tool can help them to overcome the sense of isolation by providing a structure for peer support.

**References**


Grayson, D: 1996, “Research on learning and implications for how we should teach science”. Saarmste proceedings 1996 pp. 7 - 17