Cooperative learning: Exploring its effectiveness in the Physics classroom

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Abstract

This paper reports on the results of an action research to explore the effectiveness of using cooperative learning strategies on students' academic achievement, their understanding of physics concepts and their motivation to learn in the physics classroom. The study involved a secondary four express physics class of 41 students in a neighbourhood school. Various cooperative learning structures were used to teach the topics on ‘Current Electricity' and ‘D.C. Circuits' over a period of about 8 weeks. During this period, teacher-crafted pre- and post-intervention tests were administered to the class. A questionnaire survey was used to examine students' motivation to learn and perceptions of their learning experiences before and after the treatment period. A class using traditional method of teaching was also involved in the study as a control. The effects of using cooperative learning on students' academic achievement and their motivation to learn were examined through the analysis of the results of the pre- and post-tests and students' perception surveys, while the extent of using cooperative learning on helping students achieve a better understanding of physics concepts was examined through the qualitative analysis of the students' journals. The results showed that the use of cooperative learning does increase students' academic achievement, helps students to achieve a better understanding of physics concepts and increases students' motivation to learn.

Introduction

The purpose of this action research is to explore the effectiveness of using cooperative learning strategies on students' academic achievement, their understanding of physics concepts and their motivation to learn in the physics classroom.

In many countries, there has been a decline in the number of students wishing to continue with physics (Woolnough, 1994). A number of factors have been identified by previous researchers as contributing to this decline. Smithers (2006) noted that the study of physics in schools and universities is spiralling into decline as many teenagers believe it is too difficult. Sillitto and MacKinnon (2000) noted that physics has an image of being both `difficult' and `boring'. Williams, Stanisstreet, Spall, Boyes and Dickson (2003) observed the major general reasons for students finding physics uninteresting are that it is seen as difficult and irrelevant: physics deals with abstract concepts and students find these concepts difficult to grasp.

The domain of electricity is the field where most research on students' learning difficulties is available. Psillos (1998) found that the emerging picture world-wide is not promising given that an adequate knowledge of, for example, electrical circuits has rarely been acquired by students by the end of secondary education. Students find the concepts in electricity and magnetism difficult as the invisible nature of electricity and magnetism make these topics abstract. These same topics were cited by students as a reason for physics being seen as ‘boring'.

In 2005, the Ministry of Education in Singapore embarked on “Teach Less, Learn More” (TLLM) by focusing on improving the quality of interaction between teachers and learners so that our learners can be more engaged in learning and better able to achieve the desired outcomes of education. It calls for all educators to reflect on why they teach, what they teach and how they teach.

AAAS (1990) noted that the collaborative nature of scientific and technological work should be strongly reinforced by frequent group activity in the classroom. Scientists and engineers work mostly in groups and less often as isolated investigators. Vygostsky (1978), (cited in Reveles, Cordova & Kelly, 2004), emphasized that sociocultural theory posits the interwoven nature of learning and development within and among students as they engage in concerted activities in a classroom community. Learning often takes place best when students have opportunities to express ideas and get feedback from their peers (AAAS, 1990). Students take action and interact with others to construct the contextual knowledge of the classroom. Their learning of and about science is therefore inseparable from the surrounding environment in which it takes place (Reveles et al., 2004).

Cooperative learning

According to Johnson and Johnson (1993), cooperative learning is the structuring of small groups so that students work together to maximize their own and each other's learning. Over 500 research studies back the conclusion that cooperative learning produces gains across all content areas, all grade levels, and among all types of students including special needs, high achieving, gifted, urban, rural, and all ethnic and racial groups. In terms of consistency of positive outcomes cooperative learning remains the strongest researched educational innovation ever with regard to producing achievement gains (Kagan, 1999).

Relationship between cooperative learning and students' academic achievement

In a meta-analysis of 122 research studies from 1924 to 1980 that compared cooperation, competition and individualistic learning, Johnson and Johnson (1988) found that cooperative learning (CL) promotes higher achievement than competitive or individualistic learning. The results hold for several subject areas and a range of age groups from elementary school through to adult. They found that students with cooperative experiences are more able to appreciate the perspective of others, are more positive about taking part in controversy, have better developed interaction skills, and have a more positive expectation about working with others than students from competitive or individualistic settings.

Slavin (1980) reviewed 28 primary field projects lasting at least 2 weeks in which CL methods were used in elementary or secondary school. He concluded that:

1. For academic achievement, cooperative learning techniques are no worse than traditional techniques, and in most cases they are significantly better.
2. For low level learning outcomes, such as knowledge, calculation, and application of principles, CL techniques appear to be more effective than traditional techniques.
3. For high level cognitive learning outcomes, such as identifying concepts, analysis of problems, judgement and evaluation, less structured CL techniques that involve high student autonomy and participation in decision-making may be more effective than traditional individualistic techniques.

In the same review, Slavin found that structures like TGT (Teams Games Tournaments) showed relatively consistent positive results on student achievement, race relations, mutual concerns, and other variables. Research on STAD (Student Teams Achievement Divisions) further supports the positive effects of structured CL techniques on academic achievement and race relations (Slavin, 1980).

Slavin (1983) analysed 46 controlled research studies which were conducted for an extended time in regular elementary and secondary school classrooms. Among the studies examined by Slavin, 63% showed superior outcomes for CL, 33% showed no differences, and only 4% showed higher achievement for the traditional comparison groups. Achievement gains were found in almost all (89%) of the studies which used group rewards for individual achievement (individual accountability). When individual accountability was absent, achievement overall was about the same as in comparison classrooms. In another review, Slavin (1989) identified 60 studies that contrasted the achievement outcomes of CL and traditional methods in elementary and secondary schools and found that there is wide agreement among reviewers of the CL literature that cooperative methods can and usually do have a positive effect on student achievement. However, achievement effects were only seen for cooperative structures that incorporate positive interdependence and individual accountability.

The lowest achieving students and minority students in general benefit most but the benefit obtained for the lower achievers is not bought at the expense of the higher achievers; the high achieving students generally perform as well or better in cooperative classrooms than they do in traditional classrooms (Kagan, 1994).

Relationship between cooperative learning and students' understanding of concepts

In general, past research has found that cooperative efforts produce higher-quality problem solving than do competitive efforts on a wide variety of problems that require different cognitive processes to solve. Possible reasons why cooperation may increase problem-solving success include the exchange of information and insights among cooperators, the generation of a variety of strategies to solve the problem, increased ability to translate the problem statement into equations, and the development of a shared cognitive representation of the problem (Qin, Johnson & Johnson, 1995).

Schwarz, Neuman and Biezuner (2000) presented a classroom study showing that two students working together can make learning gains even though both students entered the peer learning situation with low levels of competence. The thrust of the research on peer learning shows that when peers engage in dialogues and discussions (even arguments) that are relevant to both the task at hand and to initial misconceptions, cognitive gains can result from the peer interactions. The main purpose of using peer learning in schools is to sharpen academic skills such as listening and communication, and to enhance subject matter mastery by promoting deeper levels of understanding based on discussion and a free exchange of ideas (De Lisi, 2002).

In an experiment conducted by Heller, Keith and Anderson (1992) to investigate the effects of cooperative group learning on the problem solving performance of college students in an introductory physics course, it was found that better problem solutions emerged through collaboration than were achieved by individuals working alone. In well-functioning cooperative groups, students can share conceptual and procedural knowledge and argument roles, and request clarification, justification, and elaboration from one another, so a better solution emerges than could be achieved by individuals working alone (Heller et al., 1992).

Relationship between cooperative learning and students' motivation to learn

Among the studies that explore student motivation to learn as a result of cooperative-learning environments was that done by Nichols and Miller (1994) on high school students studying algebra. Their results indicated that CL treatment produced motivational effects. Wang, Haertel and Walberg (1993) also found a strong correlation between motivation to learn and student achievement. Peterson and Miller (2004) compared the experiences of college students during CL and large-group instruction and found that the most consistent results of this study related to student motivation, all aspects of which were more positive during cooperative learning. They found that during CL, students were more engaged. Some of the CL strategies such as Slavin's methods (TGT and STAD) include a unique scoring system that provides students with maximum opportunity to improve their achievement scores by comparing their present level of achievement to their own previous level, without reference to the scores of other students in the class. This individualised reward system enhances motivation (Sharan, 2002).

While there is a growing consensus among researchers about the positive effects of cooperative learning on student achievement as well as a rapidly growing number of educators using CL at all levels of schooling and in many subject areas, there is still a great deal of confusion and disagreement about *why* cooperative learning methods affect achievement and, even more importantly, *under what conditions* CL has these effects. Researchers investigating CL effects on achievement have often operated in isolation from one another, almost on parallel tracks, and some describe theoretical mechanisms to explain achievement effects of CL that are totally different from the mechanisms assumed by others (Slavin, 1996). There is still much to be discovered such as, which kinds of students, which techniques, and in which subjects do CL techniques have positive effects.

Research questions

The research questions formulated for the study are as follows:

Question 1: What are the effects of the use of cooperative learning strategies on students' academic achievement?

Question 2: To what extent does the use of cooperative learning strategies help students achieve a better understanding of physics concepts?

Question 3: To what extent does the use of cooperative learning strategies affect students' motivation to learn?

Students' academic achievement was measured by looking for any significance difference in the mean scores between the pre- and post-intervention tests for the CL (cooperative learning or treatment) class and at any significance difference in mean scores for the post-intervention tests between the CL and the TT class (a comparable class using traditional method of teaching).

To measure if students have achieved better understanding of physics concepts, in addition to examining whether there are any significant differences in the mean scores for the post-intervention tests between the CL and the TT class, the students' science journal entries were evaluated using the rubrics in the 6 facets of understanding developed by Wiggins and McTighe (2001). In their theory of understanding, they viewed understanding as multi-faceted. The six-facets of understanding are most easily summarized by specifying the particular achievement each facet reflects. When we truly understand, we:

1. can *explain* how things work, what they imply, where they connect and why they happened;
2. can ask the learner to *interpret*, translate, make sense of, show the significance of, decode and make a story meaningful;

3. can *apply* and effectively use and adapt what we know in diverse contexts and reveal students innovation in application;
4. have *perspective*, i.e. we can infer assumptions upon which an idea or theory is based; know the limits as well as the power of an idea (i.e. see the big picture);
5. can *empathise* by using one's imagination to see and feel as others see and feel; listen and hear what others often do not;
6. have *self-knowledge* to question our own understanding and are also aware of what we do not understand and why understanding is so hard.

These six facets of understanding allow us to assess understanding through performance.

The effects of using CL on students' motivation to learn were examined through the analysis of the pre- and post-intervention perception surveys.

Research design

The Backward Design (Wiggins & McTighe, 2001) was used in the research design (see Table I). MOE (Ministry of Education) syllabuses, the 6 facets of understanding, the different cooperative learning strategies, were some of the considerations when planning the design.

Table I: Backward Design

Key design questions	Design considerations	Filters (design criteria)	What the final design accomplishes?
What are the effects of the use of cooperative learning strategies on students' academic achievement?	· MOE syllabus · Teachers' expertise · Pre- and post-test questions	· Concept based · Engaging activity · Valid · Reliable	· A better understanding of 'Current Electricity' and 'D.C. Circuits' · Significant difference in mean scores between pre- and post-intervention tests of the CL class but not in the TT class. · Significant difference in the mean scores of post-intervention tests between CL and TT class

To what extent does the use of cooperative learning strategies help students achieve a better understanding of physics concepts?	· 6 facets of understanding · Cooperative learning strategies · Science Journals	· Sufficient authentic work · Feasible · Valid · Reliable	· Opportunities for students to demonstrate the facets of understanding (Wiggins & McTighe, 2001) in their science journal entries · Significant difference in mean scores between pre- and post-intervention tests of the CL class but not in the TT class
To what extent does the use of cooperative learning strategies affect students' motivation to learn?	· Cooperative learning strategies · Teachers' knowledge and skill in using cooperative learning strategies · Pre- and post-perception survey on motivation	· Engaging activities · Cooperative students	· Arouse interest in the learning of physics

Methodology

The study is an action research involving 41 secondary four express1 [1] students (17 male, 24 female) in a neighbourhood school in Singapore. The students are 16 years old. The group comprised of 56.1% Chinese, 22.0% Malays, 14.6% Indians and 7.3% others. Singaporeans made up a majority of the sample (91.6%), 3.3% were permanent residents, and 5.1% non-Singaporeans.

After explaining to the class about the rationale of the research and the objective of the research, a pre-test on the topic ‘Current Electricity' was administered to the class. To ensure the tests' validity and comparability of the pre and the post-intervention tests for each topic, a table of specifications was drawn up to facilitate the crafting of test questions. The test items were crafted to include 30% of the marks on knowledge with understanding and 70% of the marks on handling information. This is in line with the Cambridge GCE ‘O' Level Science syllabus guidelines given by the Singapore Examinations and Assessment Board. Based on the same guidelines, 20%

[1]Students in Singapore secondary schools are streamed into special, express, normal academic and normal technical streams according to their PSLE (Primary Six Leaving Examination) results. PSLE is a national examination taken by all primary six students at the end of six years of primary education. Students from the special and express streams study four years of secondary education before taking the GCE ‘O' level examinations while, the normal academic and normal technical students may or may not continue to take the GCE ‘O' level examinations after four years of secondary education.

out of the total marks of 25 were on multiple-choice items while the rest of the 80% marks were on structured questions. (It was stated in the GCE ‘O' Level Science syllabus that 23.5% of the marks in the written paper are based on multiple-choice items, 52.9% are based on structured questions and 23.6% are based on free-response questions.) The items selected were based on the learning objectives of the topic. A parallel set of questions was selected for the post tests. The duration of the pre- and post- intervention tests were both 30 minutes. The pre- and post-intervention tests were first crafted by the first author and then validated by the second author.

A pre-survey, developed by the researchers, to examine pupils' motivation and perceptions of their learning experiences was administered to the class before the topic was taught. Various cooperative learning structures were then used with the treatment group to teach the topic. The structures include think-pair-share, think-pair square, Jigsaw, write-pair-square, numbered heads together, pairs-check and STAD.

Students were grouped in fours (with the exception of one group which has five members) for most of the structures. The students were allowed to select their own groups based on the seating position in the laboratory. However, the teacher had earlier placed them in their seating arrangement by having a balanced mix of ethnic group and male/female students. The five key components, positive interdependence, face-to-face promotive interaction, individual accountability, social skills and group processing were structured in the cooperative learning activities whenever possible. The teacher monitored the groups closely during the lessons.

After each sub-topic, students made entries in their individual science journals, with the help of journal prompts. Some of these journals prompts were as follows: “3 things I have learnt”; “2 things I do not know”; “Your friend was absent from school when this topic was taught in class. Write a note to your friend explaining to him/her what you have learnt on series circuit. Write down any useful formulas related to series circuits and give examples to illustrate your explanation.”; and scenarios in which students have to explain how a given numerical problem is solved correctly.

At the end of the topic, the post- intervention test was administered. The same procedure (pre-test, CL lessons, journal writing and post-test) was used on the topic of ‘D.C. Circuits'.

The TT class consists of 39 students and was taught by another teacher who did not use cooperative learning. To check if the two samples were comparable, an independent t-test on the pretest mean scores of the CL class vis-à-vis the TT class was performed. The p-value obtained for 'Current Electricity' was 0.303, while that for 'D.C. Circuits' was 0.641. Since both p values were greater than 0.05, there was no significant difference in the pre-test scores between the CL and the TT class on both topics involved in this study.

At the end of 8 weeks, a post-motivation survey was administered to examine students' motivation to learn and perceptions of their learning experiences. Table II shows the time-line for the study.

Table II: Timeline of Study

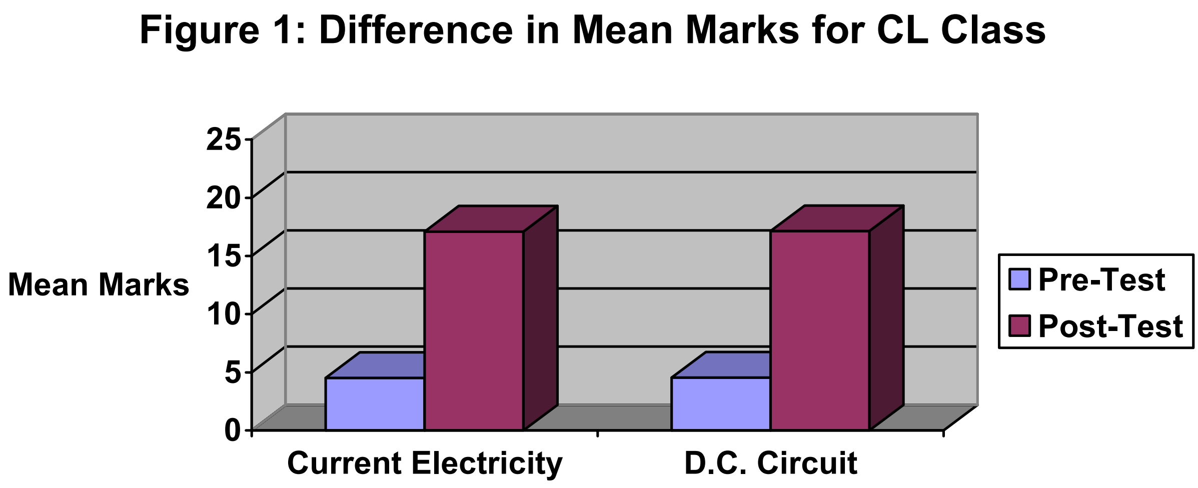
Week	Activity
1	• Explain to CL and TT class about the research. • Administer pre-survey on motivation. • Conduct pre-test on 'Current Electricity'.
2 – 5	• Use cooperative learning strategies in teaching 'Current Electricity' for CL class. • Students do journal writing after each sub-topic. • Conduct post-test on 'Current Electricity'. (Week 3 of study was disrupted as the class had to attend a school camp.)
6 – 7	• Conduct pre-test on 'D.C. Circuits' • Use cooperative learning strategies in teaching 'D.C. Circuits' for CL class.
8	• Students do journal writing. • Conduct post-test on 'D.C. Circuits' • Administer post-survey on motivation.
9- 10	• Data Analysis

Data analysis

Students' academic achievement

The students' academic achievement was analysed using the difference in mean marks achieved between the pre- and post-intervention tests for both topics. For the topic on 'Current Electricity', the CL class achieved a mean mark of 4.512 and 17.098 for the pre- and post-intervention tests respectively. For the topic on 'D.C. Circuits', the mean marks achieved were 4.539 and 17.128 for the pre- and post-tests respectively. For both topics, the improvements are quite consistent. These results are illustrated in Figure 1.

Figure 1: Difference in Mean Marks for CL Class



Paired t-tests performed on the mean pre- and post-intervention test scores on both topics (Current Electricity and D.C. Circuits) of CL class showed results were significant as both p-values were less than 0.05 (see Table III).

Table III: Comparing the mean pre- and post-intervention test scores of CL class

Topic	Paired Difference		p-value
	Mean	Std Deviation	
Current Electricity	12.586	4.589	0.000
D.C. Circuit	12.590	5.660	0.000

For the TT class, the mean mark achieved for the pre-test was 3.789 while the mean mark for the post-test was 17.361 for the topic on 'Current Electricity'. For the topic on 'D.C. Circuits', the mean mark achieved for the pre-test was 5.000 while the mean mark for the post-test was 8.000. Figure 2 illustrates these results.

Figure 2: Difference in Mean Marks in TT Class

Figure 2: Difference in Mean Marks in TT Class

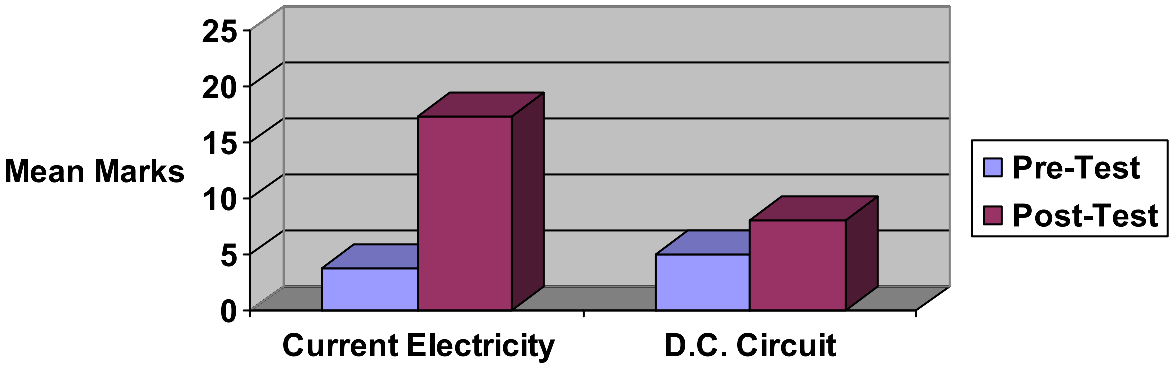


Table IV illustrates the mean scores achieved in the post-interventions scores for both the CL and the TT class for both topics.

Table IV: Comparing the mean post-intervention test scores of CL and TT class

Sample	Topics	Mean post test score	Standard deviation
CL class (N=41)	Current Electricity	17.098	4.048
	D.C. Circuits	17.128	4.878
TT class (N=39)	Current Electricity	17.361	4.722
	D.C. Circuits	8.000	4.928

Independent t-tests performed on the mean post-intervention test scores of CL class and those of the TT class showed that there was no significant difference in the results for 'Current Electricity' as the p value of 0.906, is greater than 0.05. However, for the topic on 'D.C. Circuits', the difference in results was significant as the p value = 0.000, ie. less than 0.05.

Students' understanding of Physics concepts

Students' journals in the CL class were evaluated on how students understand the concepts in 'Current Electricity' and 'D.C. Circuits'. The 6 Facets of Understanding (Wiggins & McTighe, 2001) were used to gauge pupils' understanding. All the pupils were able to recall 3 items (such as definitions, formulas, measuring instruments, and so forth). In one of the journal entries in response to a particular series circuit and the prompt: “Dave said that the ammeter reading was 0.6 A, while Jane said it was 0.3 A. Mike argued that the ammeter reading should be 0.2 A. Who do you think is right? Explain your answer.”; 23 students demonstrated the facet ‘explanation', 38 students demonstrated the facet ‘interpretation' 41 students demonstrated the facet ‘application' while 23 demonstrated the facet ‘perspective'.

The students who demonstrated the facet of 'explanation' were able to give at least a 'developed explanation', that is, an account that reflects some personalized ideas. Some of the students were also able to give 'in-depth explanation', supporting their answers with electricity concepts which they have learnt. A typical explanation was:

"Mike is right. As the current is same through every component, the total current supplied from the battery (is) shared between components. Therefore resistance is 2 + 4 = 6 Ω, using the formula V = IR."

The thirty eight students who demonstrated the facet 'interpretation' were able to give a helpful interpretation of how Dave and Jane arrived at their answers. All forty one students were skilled in applying the knowledge learnt in this journal prompt. The twenty three students who demonstrated the facet 'perspective' indicated that they were aware of different points of view and were able to give a reasonably critical and comprehensive look at all the points of view. For example, one student, Gloria, wrote,

"*Dave is wrong as he uses* $\frac{1.2V}{2\Omega}$ *= 0.6 A. It is wrong because the potential difference in each resistor is different, thus he cannot use 1.2 V divided by 2 Ω. Jane is wrong too as she uses* $\frac{1.2V}{4\Omega}$ *= 0.3 A. The reason is the same as Dave. The e.m.f of the circuit is only for the total resistance."*

In another journal entry associated with a parallel circuit, where the prompt was: “In the following circuit, one of your group members said that the effective resistance is 5 Ω. Is he/she correct? If not, explain to him/her how you would find the effective resistance of the circuit. Explain also how you would find the current that passes the 2 Ω and 3 Ω resistors.”; 15 students demonstrated the facet ‘explanation', 30 students demonstrated the facet ‘interpretation' 35 students demonstrated the facet ‘application' while 15 demonstrated the facet ‘perspective'. As in the previous case, those who demonstrated the facet 'explanation' were able to give 'detailed' or 'in-depth' explanation of how they arrived at their conclusions. This facet was only shown in fifteen journal entries as the rest of the students did not give any explanation. They only wrote down the correct solution, which was what would normally be required in answering a typical 'O' Level Science (Physics) examination question. The students who demonstrated the facet ‘interpretation' were able to interpret how the wrong answer was derived by one of the group member (as in the journal prompt) due to wrong concepts and formula used. In finding the effective resistance, a typical explanation from the students was,

"No. He/She is wrong.

$$\frac{1}{R}=\frac{1}{2}+\frac{1}{3}=\frac{6}{5}$$

$R = 1.2\ \Omega$.

The correct formula is by using $\frac{1}{R}=\frac{1}{R_1}+\frac{1}{R_2}$ *as it is in parallel. He/She is wrong*

because she probably uses the series formula which is $R = R_1 + R_2$."

The other facets were not demonstrated as it was not possible to interpret these facets accurately from the students' journals entries alone.

Students' motivation to learn

The effects of using cooperative learning on pupils' motivation to learn were examined through the analysis of the pre- and post-perception surveys. Figures 3.1 and 3.2 illustrate the results of the perception surveys. At the end of the study, more students like Physics lessons, ask scientifically oriented questions, like to learn things that are challenging, able to complete Physics homework on time, enjoy group work, prefer learning in group than alone, felt that group work has aroused their interest in learning Physics and have learnt from their group members.

Figure 3.1: Motivation to Learn

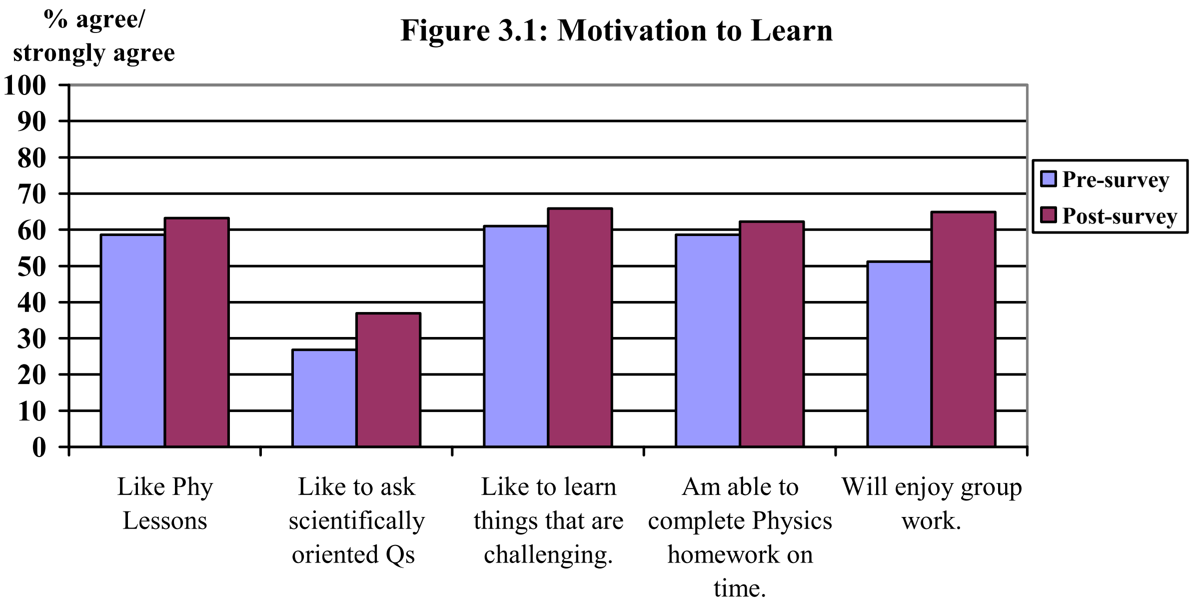
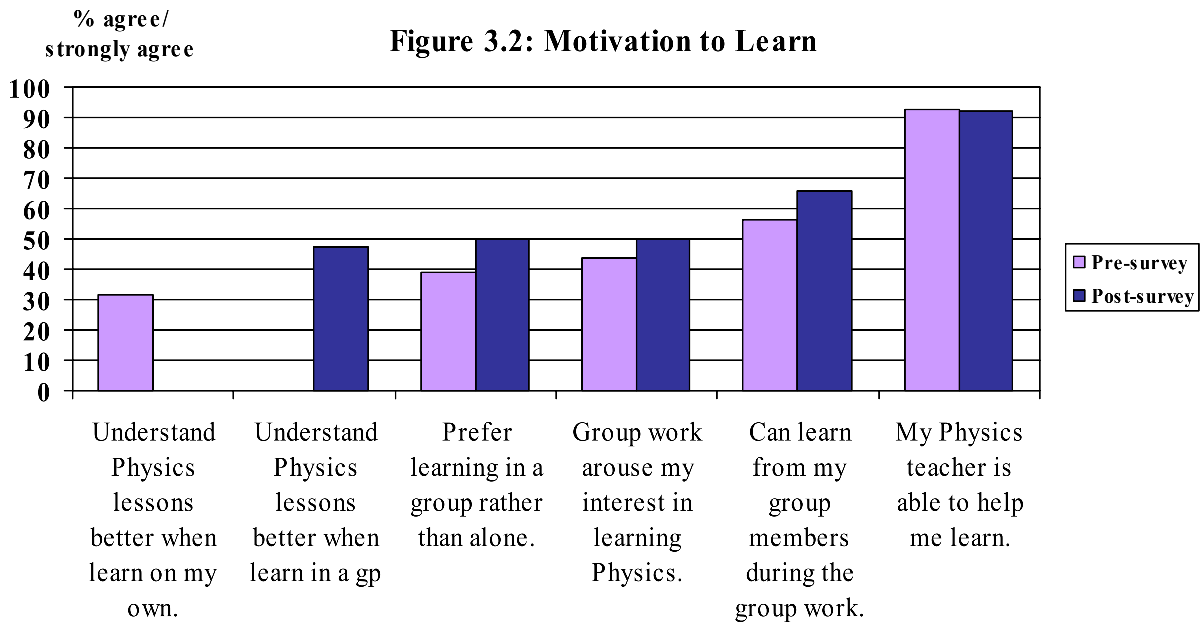


Figure 3.2: Motivation to Learn



Discussion of findings

The results of the study support the view that the use of cooperative learning strategies contributes to higher students' academic achievement in relation to physics topics.

This higher achievement seemed to be consistent and sustained for both topics under study as there was significant difference in mean scores between the pre- and post-intervention tests for both topics. When compared with the TT class, the CL class had performed better for the ‘D.C. Circuits' topic. For the TT class, although there was a marked improvement between the pre- and post-intervention test for the topic on “Current Electricity”, this was not sustained for the topic on “D.C. Circuits”. In fact, this class performed very much below expectation for the second post-test. One possible reason for the great disparity in the mean marks for the post-intervention tests between the two topics could be due to the more difficult concepts in ‘D.C. Circuits' topic, as these concepts require higher order thinking.

The use of cooperative learning strategies also seemed to promote better understanding of the electricity concepts as could be seen from the students' science journal entries where they demonstrated the facets of understanding. In fact, all the students were able to solve the numerical questions given in the journals. The majority of them were able to describe how the results should be calculated and why the fictitious persons in the question were wrong. Although the results indicated that not all 41 students demonstrated all the facets, this is likely due to the fact that they were not used to giving detailed explanations on how they derived their answers and their thinking behind their solutions, as these were not the routine kind of questions in the Cambridge GCE ‘O' level Science (Physics) examinations.

When asked to write what they like about lessons in 2007, 19 out of 41 students cited things linked to group work, such as, ‘there is more group work', ‘group discussions in each topic', ‘studying in groups', ‘new methods of studying in group', ‘the group teaching and quizzes'. Others wrote that they could understand the topics better. From here and the results of the perception surveys, students were generally seen to be more motivated to learn because of the use of cooperative learning strategies.

However, there were a small minority who appeared not to be motivated by the use of cooperative learning strategies. When asked what they did not like about the lessons, two students wrote that their group members were not doing their part and six students wrote that they did not like the group work. These findings were in line with those reported in a study carried out by Hancock (2004) on cooperative learning and peer orientation effects on motivation and achievement. Hancock found out that students who desired to work with others seemed to be more motivated to learn in settings that maximized student interaction than were students who desired to work alone. Another possible reason could be that students have accustomed to learn passively from teachers. They are used to taking down notes, doing worksheets and preparing for tests and examinations. Students prefer to listen to their teachers, rather than their peers, especially when it comes to difficult academic content and material.

Limitations of the study

There are some factors which may threaten the validity of this study. An example is the teacher factor as the teachers teaching the two classes are different. However this is a factor that could not be avoided because the primary researcher involved in this study has only one Physics class at the secondary four level. Recommendation for further study could be that the study be replicated with the primary researcher swapping teaching method with the teacher who taught the TT class, i.e. the primary researcher now uses traditional method of teaching while the other teacher uses cooperative learning.

In the data analysis, it was not possible to interpret two facets accurately, namely, *empathy* and *self-knowledge*, from the data collected. Although the two facets were not demonstrated in the data collected, it does not necessarily mean that the students have not achieved these two facets. For future studies, researchers could include video recording of the group interaction during cooperative learning lessons to address this problem.

Random sampling method could not be used in this study due to various constraints. Instead, intact classes and convenience sampling were used. As a result, the results of this study cannot be generalized to other levels and streams as students from different age groups may respond differently to cooperative learning. Similarly, the results also cannot be generalized to other school setting as this is a classroom research which is unique to the teacher and the students in this class.

There are many different types of cooperative learning strategies as well as variations of these strategies. The variety is necessary because the structures have different functions or domains of usefulness (Kagan, 1989). For example, Colour-Coded Co-op cards are designed for efficient memory of basic facts; Pairs-Check is effective for mastery of basic skills; and Numbered Heads Together is designed for review or checking for comprehension. How effective is the use of cooperative learning as a teaching and learning strategy has to depend on how effective the teacher is in using the relevant and different strategies for different purposes.

Conclusion

Within the limitations of the study, it was found that the use of cooperative learning does increase students' academic achievement, helps students to achieve a better understanding of physics concepts and increases students' motivation to learn. Both the teacher and students gained much from this study. The students gained a better understanding of the concepts and in the process of taking the pre-tests and post-tests, they discovered that they actually like sitting for the pre-tests as these tests give them an idea of what to expect from the topics, and in a way, make the topics easier to comprehend. This is a surprising discovery for the teacher which could lead to further research.

The researchers have also gained valuable insights on the design of the CL lessons, the crafting of the journal prompts as a form of reflection and the importance of facilitating cooperative learning activities to allow students to connect new and past experiences. By examining the extent on how the use of cooperative learning strategies can help students achieve better understanding of physics concepts, the researchers have gained valuable insights into how well students understand the concepts; whether students are able to explain how things work, whether students can make connections to different concepts they learn; whether students are able to interpret, apply and effectively use and adapt what they know in diverse contexts, whether students can infer assumptions upon which an idea or theory is based. It was also interesting to note that different cooperative learning strategies achieve different purpose. For example, the teacher-researcher noted that the students were extremely excited when she implemented STAD and TGT. All the students were on task and were strongly motivated to perform well for their groups. Through the use of these cooperative learning strategies, the teacher-researcher found that the students' motivation to learn increases tremendously and this may have contributed to them showing higher achievement.

With this new knowledge, future physics lessons could be designed with appropriate instructional material and suitable cooperative learning strategies so as to engage the students meaningfully, which is line with the MOE's focus on promoting engaged learning in TLLM. Hopefully, this will arrest the problem of students being disinterested in the learning physics. The valuable insights gained from this study will contribute towards building the corpus of local knowledge on the effectiveness of cooperative learning as a teaching and learning strategy in the physics classroom.

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