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Cooperative Learning in Engineering Education: a Game Theory-Based Approach*

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This paper describes some findings derived from teaching a class of engineering students organized into cooperative learning groups. We used the "iterated game" and "intergroup competition" based on game theory for group arrangement and class management so that students were encouraged to learn cooperatively. The performance of the cooperative learning class was compared to other classes that did not implement cooperative learning groups. The results indicate that students in cooperative learning class significantly outperformed students in other classes. Student feedback showed that cooperative learning effectively lifted student motivation to learning.

Keywords: cooperative learning; game theory

1. Introduction

Engineering and science education require different epistemological models. Scientific theories are abstract models of the real world. The ability to filter out irrelevant details is essential to scientific thinking. Engineers build actual structures to solve real world problems. Engineers should be able to see from every aspect, not to ignore any detail that may cause the failure of their projects. Cooperation is the way to integrate knowledge and experience from experts of different disciplines. Cooperative learning is very important and effective in engineering education.

When it comes to working or learning, "cooperation" has always been the key to human survival [1]. However, it was not until the 1970s that cooperation was applied to classroom teaching. As a teaching strategy, cooperative learning has been proven to be effective by many scholars and experts. Through peer interaction, cooperative learning enables students to learn from one another, which produces positive impact on learners [2]. Lauzon [3] also stated that the best way for students to learn is through exchange of opinion, discussions and sharing of feelings, which lead to new viewpoints and interesting solutions. All these findings consistently indicate the importance of cooperation.

Teachers intend to create learning environments that encourage students to cooperate and learn. However, competitive behaviours are often observed among students because they feel that they have to gain advantage over others in order to succeed eventually [4]. Kohn [5] indicated that competitive learning models may have negative repercussions on students, such as anxiety, selfishness, feelings of distrust and breakup of interpersonal relationship. These are results of unproductive competitions that emphasize only winning and losing. Therefore, the best ways to make learning effective are to exclude all factors that hinder cooperation in class and make competition a motive for group cooperation.

Group members may choose either to be cooperative with others or not. The situation is the same in the prisoner's dilemma as described in game theory. Prisoners hesitate over the decision whether to cooperate with others or not. At the beginning, cooperation is not established because their only concern is their own benefits and they choose to defect from their accomplices [6]. Later, they realize that cooperation is the most efficient strategy in the dilemma [7].

In cooperative learning, some resources are shared by all members in the same way that people share public goods in game theory wherein all people get to share information provided by others. Even those who do not contribute to the group can use those resources. However, many people may be selfish and may want to enjoy public property that can be easily accessed. This often results in unwillingness to cooperate and therefore restricts the growth of shared benefits.

The objective of this paper is to study and analyse cooperative learning in engineering education through a pedagogical experiment. A class of 32 students from an engineering school is the subject. The teacher designed and implemented classroom activities that encourage cooperative learning behaviour based on game theory. The performances between the experimental class and three other classes of similar sizes that use conventional lecture-based teaching are compared.

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2. Literature review

2.1 Cooperative learning

Cooperative learning provides a learning environment where heterogeneous group members learn together and serve as information providers for one another. Through interaction, discussion and knowledge exchange, members adjust their viewpoints and eventually accomplish assignments together [8, 9].

Johnson & Johnson [9] pointed out five vital elements for the successful implementation of formal cooperative learning groups:

(1) positive interdependence,
(2) face-to-face promotive interaction,
(3) individual accountability/personal responsibility,
(4) teamwork skills,
(5) group processing.

Informal cooperative learning groups differ from the formal variety. In informal cooperative learning groups, individual accountability is emphasized, low interdependence exists and fewer discussions take place. Only one leader is appointed to direct members' participation, which results in most members being unable to learn teamwork skills or in members failing to work effectively together [10]. Merely putting students in one group cannot guarantee efficient cooperation among learners.

According to Steiner's research, the following three phenomena that might weaken cooperation can be observed in group members during their learning [11]:

(1) Social Loafing: Social loafing is the tendency to reduce individual effort when working in groups, compared to the greater individual effort expended when working alone [12].
(2) Free Riding: Free riding occurs when an individual does not render a proportional amount of the work and yet takes more from the total output of the group [13, 14].
(3) Sucker Effect: Sucker effect occurs because of unfair payback—each member shares the same payback regardless of the proportion of his/her contribution [15].

When cooperation takes place, a certain kind of interactive mode will occur. Johnson & Johnson indicated that active mutual reliance results in interaction, whereas passive mutual reliance brings about conflict. Without mutual reliance, there will be no interaction [16]. Johnson & Johnson [17] analysed four competitive situations:

(1) negative relationships,
(2) bullying,
(3) aggression,
(4) conflict.

They also analysed five cooperative situations:

(1) interpersonal attraction,
(2) group cohesion,
(3) belonging,
(4) social support,
(5) ending isolation and alienation.

A sense of belonging and achievement gained through peer cooperation and moderate competition are important factors for improving self-confidence [18]. In cooperative learning, the concept of reliance among group members is of great importance. Positive interdependence guarantees efficient learning. Among group members, the absence of positive relationship, moderate competition or the existence of individualism can lead to poor learning [19].

In the late 1940s, Deutsch [20] proposed a theory in which competition and cooperative learning occur within the setting of a goal structure. Goal structure refers to interactive patterns between learners when they work on intended goals. Three instructional goal structures have been defined:

(1) cooperative,
(2) competitive,
(3) individualistic.

Among the three, cooperative goal structure provides the best condition for group cooperation. Different incentives were used in experiments to stimulate cooperation and competition. After group members cooperatively accomplished tasks, they shared rewards evenly. In subsequent research studies, the same method was applied repeatedly in order to create cooperative and competitive environments. When a group has a certain goal and all its members share the same goal, group goals become linked to individual goals [21].

Johnson later expanded on Deutsch's social interdependence perspective by stating that when an individual decides to interact with others, cooperation occurs, and when an individual chooses to compete with others rather than interact, group learning is hindered. All these are concerned with individual choices about whether to cooperate or to compete. Kohn [5] noted that competition within a group aims at individual performances, whereas intergroup competition aims at group achievements. Accordingly, where there is competition there is progress. However, whether competition is a positive factor for cooperative learning will depend on how it is applied.

Felder [22] proposed four dimensions for learning and teaching:

(1) sensing/intuiting,
(2) visual/verbal,
(3) active/reflective,
(4) global/sequential.

Sensing involves observing, gathering data through the senses; intuition involves indirect perception by way of the unconscious—speculation, imagination, hunches. The visual dimension involves sights, pictures, diagrams, symbols; the auditory involves sounds, words. Active experimentation involves doing something in the external world with the information—discussing or explaining it, or testing it in some way; reflective observation involves examining and manipulating the information introspectively. Global learners make intuitive leaps and may be unable to explain how they arrive at solutions. They may be better at divergent thinking and synthesis. Sequential learners follow linear reasoning processes when solving problems. They may be strong in convergent thinking and analysis.

In cooperative learning, students provide information from various viewpoints and help other group members to learn. Through discussion and other cooperative learning activities, students gradually evolve their knowledge structures over issues and thereby achieve their learning goals. Engineering education emphasises sensing, active and global orientations in three of the four dimensions of the learning strategy proposed by Felder. The sensing orientation, which is defined as the ability to sense related facts and problems with keen observations, plays a vital role in problem solving in engineering. The active orientation, which is defined as the tendency to take an active role in processes, helps to bring engineers onto a wider range of resources for gathering information. The global orientation is defined as the ability to consider things as a whole, to make sure all potential issues are taken into account and to integrate results from various points of views. Figure 1 shows a probable learning strategy in engineering education.

2.2 Game theory

Learners may display complex behaviour, consisting of both cooperative and competitive acts. The

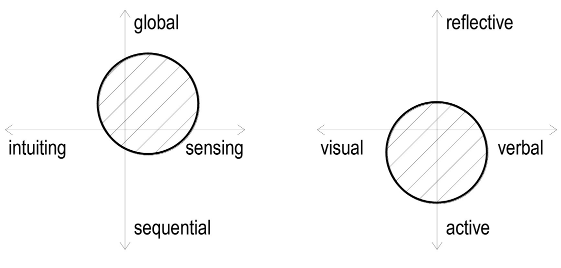


Fig. 1. Learning Strategy in Engineering Education.

situation is analogous to the prisoners' dilemma and the public goods game in game theory. Romp [23], in 1997, indicated that game theory analyses human behaviour in strategic situations by using mathematical models. It helps predict participants' future movements by working on strategies which are the results of their expected payoffs. In the prisoners' dilemma, two prisoners are isolated. Fearing that the other may defect and therefore place them in a worse position, both prisoners end up confessing to the crime, leaving prisoners in a lose-lose situation in which both prisoners lose the opportunity to get minimal jail times.

The prisoners' dilemma can be analysed as either a one-shot game or an iterated game. Each leads to a different result [24]. In one-shot games, participants' interests will not be related to each other after the game, and they would not cooperate with each other theoretically. In iterated games, where participants have chances to develop long-term relationships, the better strategy for players is to consider mutual interests and to create a win-win situation by continuous cooperation [7]. Rabin's research has proved that if one is being treated well, he or she will treat others that way too; but if one is being harmed by others, he or she tends to hurt others as a form of revenge [25]. This is consistent with the tit-for-tat strategy in Rober's research on prisoners' dilemma in 1979.

According to research by Shih, Hu, & Chen [26], cooperative learning for design workshops should have open sources of information and stages of peer evaluations; they should also encourage intergroup competitions because competition can be a motive force for cooperation. Intergroup competition can stimulate learners to interact with one another and eventually allow cooperation to occur within the group.

Public goods are goods that people share at the same level of service and quality. Individuals who make no contribution to the production of public goods can enjoy using them without reducing the availability of the goods for consumption by others. Therefore, they are non-excludable and non-rival in quality [27]. In cooperative learning, the sharing of information is similar to the sharing of public goods. In cooperative learning, information is provided by every member in the group rather than by only a minority. Therefore, instead of waiting for free riding to occur, teachers must use teaching strategies to make sure every student actively provides usable information.

2.3 Theoretical model

Game theory is a mathematical tool used to analyse gains and losses of multiple players interacting with each other. It is helpful in finding the most advantageous strategy for each player. More important, game theory can be used to derive the equilibrium state of multiple players when all players follow their most advantageous moves. The applicability of game theory does not rely on the assumption that people always put self-interest as the highest value but that all people have certain dispositions inherited and learned from their ancestors, who were able to retain advantageous positions in numerous confrontations. People may behave differently or similarly for various reasons, such as religion, culture, self-interest, emotion, or even for some unexplainable causes. However, motivations are not that important, and the things that matter are the behaviours and their consequences. In this research, game theory is used as a tool to find the relationship between experimental setups of social confrontations in learning environments and the most likely outcomes for learning groups.

2.4 Strategic game of two players

In classrooms where teachers apply cooperative learning, students decide whether to cooperate with their teammates or not after considering situations that seem to be more beneficial. Table 1 shows the gains and losses of different students. The table demonstrates that when a student and his/her partner are both willing to cooperate, the real benefit they get is $s - 1$, in which s is the gain cooperation and 1, the effort required for being cooperative. If a student cooperates while his/her partner does not, this student receives –1 benefit because he/she pays for the cooperation without getting anything in return; on the other hand, his/her partner who fails to cooperate gets an f, which is the benefit from hitchhiking. Alternatively, if a student chooses not to cooperate in the round while his/her partner does, this student gets hitchhiker's benefit f and his/her partner gets a –1. Finally, if neither of the students decides to cooperate in the round, they get 0 benefit, which means they both gain nothing and lose nothing.

2.5 N iterative game

In reality, decisions over the issue of cooperation are made repeatedly in classrooms. These can even further influence the way students interact with one another in their everyday lives. Strategies and results from previous cooperation influences the behaviour of both students in their follow-up moves. This is what is called the 'tit-for-tat' strategy. If student A benefits from mutual cooperation in the prior round, he/she will most likely choose to cooperate with B again in the next round. However, if student A cooperates while B does not, he/she will choose not to cooperate in the next round because he/she gained nothing while having to pay for the price in the first round.

If the tit-for-tat strategy is used in N iterative game, we get the result shown in Table 2. When both the student and his/her partner choose to cooperate in the first round, according to the tit-for-tat strategy, they will proceed towards cooperation. In terms of benefit, the student and partner get $n(s - 1)$ benefit, which is n multiplied by 'the benefit of cooperation minus the price of cooperation'. However, if the student cooperates while his/her partner does not, according to the tit-for-tat strategy, the two of them will not cooperate in the next game. In terms of benefit for both sides, the student gets $-1 + (n - 1)0 = -1$, which is the real benefit for cooperating in the first round plus the 0 benefit he/she gets for noncooperation starting from the second game. In contrast, the partner gets $f + (n - 1)0 = f$ because he/she gets the hitchhiker's benefit f during the first round of cooperation and gets nothing else for the rest of the round of games. Another situation is when the student does not cooperate in the prior round while his/her partner does. In this case, according to the tit-for-tat strategy, the two will not cooperate in the following rounds. The student gets benefit f for $f + (n - 1)0 = f$, whereas his/her partner gets –1 for $-1 + (n - 1)0 = -1$. The last kind of situation is when both students choose not to cooperate, there will be no future cooperation; therefore, they will both get 0 benefit.

2.6 The initial probability of cooperative behaviour of the group

In one occasion for cooperation, when someone decides to cooperate, the probability that his/her partner cooperates is p, whereas the probability that

Table 1. Game theory model: cooperation vs. noncooperation

	Cooperation	Noncooperation
Cooperation	s–1, s–1	–1, f
Noncooperation	f, –1	0, 0

s: benefit of cooperation
f: benefit of hitchhiking
The required effect for cooperation is assumed to be "1."

Table 2. Tit-for-tat vs. Withhold

	Tit-for-tat	Withhold
Tit-for-tat	n(s–1), n(s–1)	–1, f
Withhold	f, –1	0, 0

s: benefit of cooperation
f: benefit of hitchhiking
n: number of games that take place
The required effect for cooperation is assumed to be "1."

his/her partner does not cooperate is $1 - p$. The expectation value for cooperation comes from the benefit of mutual cooperation, $pn(s-1)$, plus the price for cooperation when his/her partner does not cooperate, which is $(1-p)(-1)$. The result is demonstrated in Equation (1) below.

If a person decides not to cooperate, his/her partner may have probability p for cooperating or probability $1 - p$ for not cooperating. Equation (2) shows the expectation value derived from the benefit of his/her partner's cooperation pf plus $(1-p)0$, plus the price for his/her partner's noncooperation.

p in $E(p)$ stands for the probability of cooperation:

Expectation value for cooperation:

$$Ec(p) = pn(s-1) + (1-p)(-1) = pns - pn - 1 + p = p(ns - n + 1) - 1 \quad (1)$$

Expectation value for noncooperation:

$$En(p) = pf + (1-p)0 = pf \quad (2)$$

The hypothesis states that if the expectation value of cooperation is bigger than the expectation value of noncooperation, then cooperative learning tends to happen. Therefore, the necessary condition for cooperation is $E(1) > E(0)$. According to equations (1) and (2), the inequality $E(1) > E(0)$ can be transformed into $p > 1/(n(s-1) + 1 - f)$.

$$E(1) - E(0) > 0$$
$$p(ns - n + 1) - 1 - pf > 0$$
$$p(ns - n + 1 - f) > 1$$
$$p > 1/(n(s-1) + 1 - f)$$

The inequality shows that the relation between n, s, f and p determines whether the group will be cooperative or not. The bigger the benefit cooperation brings, the more chances there are of cooperation. Assuming that $s - 1 > 0$ and that n or the number of games rises, the probability of cooperation p has higher chances to fit in the inequality $p > 1/(n(s-1) + 1 - f)$.

3. Cooperative learning course design

As described earlier in the literature review, Johnson & Johnson mentioned that cooperative situations have high correspondence with iterated games and intergroup competitions. Intergroup competition gives group members the same goal, brings about group cohesion and enables the group to undertake challenging tasks of all kinds. At the beginning, group members do not have a sense of identity towards their own group. After they go through a transition period while playing iterated games, they reach the point where they find:

- interpersonal attraction,
- group cohesion,
- belonging,
- social support,
- ending of isolation/alienation within the group.

This phenomenon occurs not only in classroom learning but also extends to everyday life. However, once betrayal takes place, cooperation stops. Cooperation requires continuous interaction between the two sides. Without chances of meeting each other in the future, cooperation will not be lasting.

3.1 Course scheme

In this research, the cooperative behaviour of students in the course "Building Code" were observed. The objective of the course is for students to become familiar with building codes and to have the ability to examine a building design's legal status. The study of building codes does not require much background knowledge. This is because the study of one part of building code does not depend on much prior knowledge of other building codes. Exchange of information among students could be effective in helping them build a more complete structure of the knowledge base for a building code.

The subjects include 123 students from four classes. Students in each class had the same average level of academic performance. As can be seen in Table 3 below, Classes A, C, and D used conventional lecture-based teaching. Classes B used Cooperative teaching.

3.2 Course design

The course design in this research includes four aspects: grouping method, course flow, test arrangements and scoring method:

(1) **Grouping Method**: Vermette [28] indicated that if teachers allow students to find their own group members during a class section, the groups tend to be homogeneous in quality. This results in limited experience or viewpoints of learners instead of immersing students in different perspectives while they try to digest what they have learned. Swing & Peterson [29]

Table 3. Teaching methods and number of students in each class

	Class A, C, D (Control Group)	Class B (Experimental Group)
Teaching Method	Lecture-based teaching	Cooperative teaching
Number of Students	33, 29, 29	32

considered heterogeneous groups that include students of different competence levels to be more beneficial for learning because low competence students can get useful learning resources from high competence students. According to a research conducted by Hooper & Hannafin [30], students with low competence performed 50% better in heterogeneous groups than in homogeneous groups. In cooperative learning, two to six students of different competence levels are assigned to each group [16]. However, as the number of group members increased to a certain level, interaction and mutual reliance among group members decrease, leaving less time for interaction for each member. According to the research discussed above, the grouping method in this study ensures that each group includes students whose academic performance ranges from high to low. Four heterogeneous groups have five members and three heterogeneous groups, four members.

(2) **Course Flow**: Each class lasts for fifty minutes. In the first ten minutes, teachers explain main ideas. During the next twenty minutes, each group receives a learning sheet for group discussion. During the last twenty minutes of the class, a test is given and is followed with a review.

(3) **Test Arrangements**: In order to increase the number of games as in the theoretical model, students receive a test during each class session. The arrangements require a test to be assigned to each group for group discussion. Tests are divided into three parts, each of which is assigned randomly to one of the group members. This saves much time because students do not have to answer all questions. However, they have to study the entire test coverage during group discussion.

(4) **Assessment Method**: Each student receives a group score and an individual score. All members share the same group score by summing up individual scores.

3.3 Course implementation

In this experimental course, every teaching session was followed by a test, with three major examinations each month. During the teaching process, some activities were repeated many times so that students could explore the importance of cooperation. This was done to create a learning situation that is similar to an iterated game and to facilitate intergroup competition.

One way to encourage cooperation is by providing rewards. In this experiment, different methods of testing and grade calculation were utilized for intergroup competition. These also provided students the chance to receive appreciation from teachers and their peers. Thus, a group's success, which is the result of group cooperation, would be the best reward.

After the experimental teaching, we examined the effects with the help of questionnaires and student interviews in order to find all possible ways to improve teaching. By interviewing students whose grades improved as well as students whose grades dropped, the factors that could influence students' achievements were revealed.

4. Results and discussion

After analysing all grades from the cooperative class by t-test, we found that teaching results differ considerably between the cooperative learning class and the lecture-based teaching classes. In the cooperative class, two opposing extremes over the issue of cooperation can be observed. Groups that cooperate well tend to advance their performances remarkably, whereas groups that fail to cooperate tend to much lower achievements. This phenomenon corresponds to the inequality derived from the theoretical model, in which when the initial state of membership fits $p > 1/(n(s-1)+1-f)$, the probability of cooperation is high. If this is not the case, cooperation tends not to be established.

4.1 Grades from monthly exams

The patterns of Classes A, B, C, and D students' monthly exam grades are shown below (Fig. 2). The students' average grades and standard deviations in each class are shown in Table 4.

According to the grades of the four classes, Class B, which used cooperative learning, demonstrated superior results in passing rates, average grades and standard deviation, revealing the positive effects of cooperative learning.

4.2 Comparisons of monthly exam grades of each group in class B

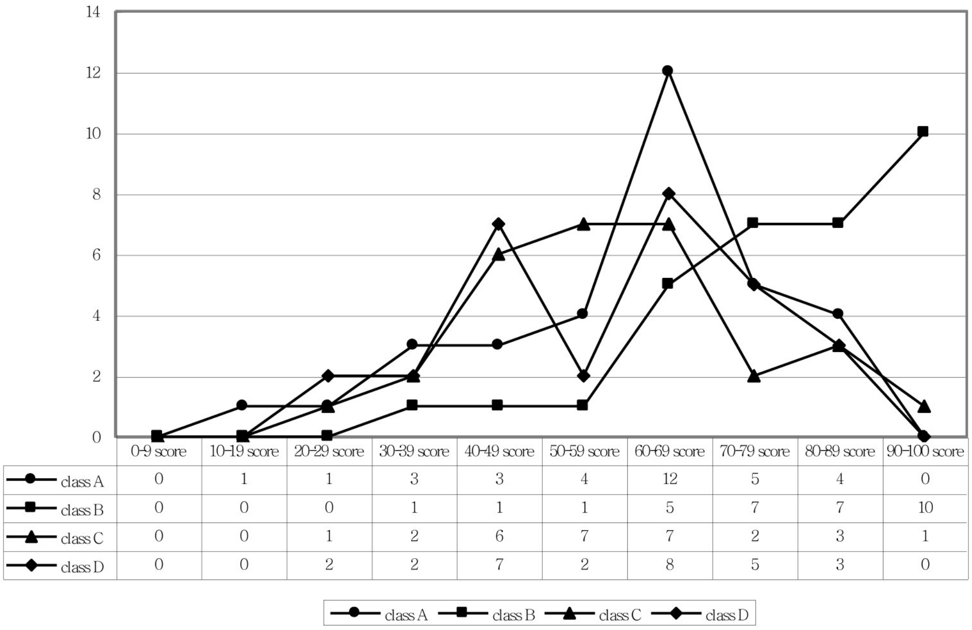
The class was divided into seven academic heterogeneous groups unit. A, B, C, D and E in Table 5 represent students' rankings in each group. For example, 1 A refers to the student in Group 1 who achieved the highest score, and 4 E refers to the student in Group 4 with the lowest score. Table 5 shows the scores for this monthly exam.

4.3 Questionnaires

The results of the questionnaire for cooperative learning are shown in Table 6.

4.4 Discussion

In this study, t-test was used as a statistical tool to



	0-9 score	10-19 score	20-29 score	30-39 score	40-49 score	50-59 score	60-69 score	70-79 score	80-89 score	90-100 score
class A	0	1	1	3	3	4	12	5	4	0
class B	0	0	0	1	1	1	5	7	7	10
class C	0	0	1	2	6	7	7	2	3	1
class D	0	0	2	2	7	2	8	5	3	0

Fig. 2. Classes A, B (cooperative learning), C, and D monthly exam grades.

Table 4. Average grades and standard deviations of each class

	Class A	**Class B**	**Class C**	**Class D**
Passing Rates	63.6%	**90.6%**	44.8%	55.2%
Average Grades	59.1	**79.0**	57.2	57.1
Standard Deviation (SD)	16.68	**15.42**	18.06	16.37

Table 5. Class B student grades in each group in monthly exam

	Individual Grades in Monthly Exam				
Group	**A**	**B**	**C**	**D**	**E**
1	97	95	83	82	**70**[1]
2	100	84	84	79	**36**[1]
3	100	98	83	**82**[1]	77
4	96	95	79	76	**73**[1]
5	90	**67**[2]	**64**[2]	**62**[2]	
6	93	**67**[2]	**55**[2]	**46**[2]	
7	92	83	74	**66**[2]	

[1] students who received the worst scores in earlier tests
[2] students who received grades below 70

analyse results from different teaching methods. Classes A, C and D followed the lecture-based teaching, whereas Class B applied cooperative learning strategy in the course design. After analysis, the P-value < 0.05 indicates that different teaching methods contribute to the differences in learning performance. Students experiencing cooperative learning had higher levels of achievement scores than those who used the regular teaching method.

As shown in Fig. 2, the majority of students' grades in Classes A, C, and D fall between 60 and 69. In contrast, the grade distribution for Class B falls mostly between 90 and 100. Moreover, Class B, which adapted cooperative learning, has a high passing rate of 90.6%, with average grades of 79 and a standard deviation of 15.42 (Table 4). These are outstanding ratings compared with those of the other three classes. The findings show that levels of performance are remarkably different between students in conventional lecture-based teaching and cooperative learning. Although it is very difficult to exclude the Hawthorne effect [31, 32, 33] from its possible influence in our study, the large difference in the average grade (58 vs. 79) strongly implies that cooperative learning still contributed to the higher levels of performance of the observed class.

Group learning has a positive effect on student learning. This can be confirmed by comparing the scores from the monthly exams among Classes A, B, C and D. In the process of learning, students in the same group shared what they have learned with one another through activities based on the principle of iterated games. Even though teachers' lecture time was significantly reduced, group learning provided students with the opportunity to learn from one another and to construct their own knowledge base more thoroughly, which enables students to learn and memorize even better.

Table 6. Questionnaire results

No.	Contents	Results
1	Which way of teaching enables me to learn more easily?	Cooperative Learning (93.1%)
2	Cooperative learning vs. raising learning interests	Helpful (93.1%)
3	Learn cooperatively with classmates vs. scores	Helpful (93.1%)
4	Learn cooperatively with classmates vs. friendship with classmates	Helpful (89.7%)
5	Your preferable way of learning	Cooperative Learning (93.1%)
6	After learning cooperatively, is it necessary for you to spend much time preparing for the monthly exam?	Not necessary (82.1%)
7	I think the advantages of cooperative learning are . . .	Members in each team help one another solve problems (68.8%)
		Know the focus of learning easily (68.8%)
8	I think the disadvantages of cooperative learning are . . .	Group grades go down if someone in the group does not cooperate. (53.1%)
		Troublesome to move desks and chairs (53.1%)
9	Which is your favorite stage while learning cooperatively?	Group discussion (48.9%)
		Announcement of group scores (48.9%)
10	Which stage in cooperative learning do you dislike the most?	Testing (48.9%)
11	While doing group discussion, how did it proceed in your group?	Discussion of the topics (92.9%)

Table 5 shows that the performances of Groups 1–4 are not affected by the presence of the previously worst performing students. Three of the four students—those whose grades are indicated in gray in Table 5—had remarkable improvements. The student who scored the lowest (36) had previously decided to quit school; this probably explains the poor performance. Group members believed that factors such as information exchange, having the same group goals, peer pressure for learning, pressure for good grades and positive feedback for good performances from peers and teachers all contribute to group cooperation. The four students with low threshold performance did not seem to be liabilities to their groups. Instead, after learning cooperatively in groups, their grades improved considerably. Groups 1–4 appeared to be successful in terms of cooperation.

Both Groups 5 and 6 consisted of four members. However, among the seven students graded below 70, 75% were from Groups 5 and 6. In terms of in-class exams, Group 5 had the worst group scores the first few times. Its scores improved gradually and even achieved best group scores three times in the end. Students in this group did not perform well initially, but later, they started cooperating with one another when they learned. After going through an iterated game situation, members knew that they could get good grades by cooperating and that they could stimulate intergroup competition by promoting their group. Individual scores improved under this circumstance. However, the student scores in the monthly exam were not satisfactory in general, because some students in this group spent less time studying this subject, as they felt that it was not important.

One student in Group 6 performed very well during evaluation. He tried hard to help teammates learn. However, intergroup cooperation failed to occur. Theoretically, by increasing the number of games and the rewards of cooperation as well as by decreasing the hitchhikers' benefit, the chances of cooperation can be raised. However, Group 6, for instance, shows that if the initial probability of cooperative behaviour is small, then the threshold for promoting cooperative behaviour would be very high. This corresponds to our theoretical model. If the probability of cooperative behaviour is low when a group is formed, then this group tends not to cooperate. From our observation, after students were grouped into teams, they had to go through a period of adjustment. When communication and mutual trust among team members fail to develop and when members begin to give up trying, noncooperative attitudes will become dominant, which will lead to poor performance. This is why teachers should pay special attention to the interaction modes of each group, especially during this critical state at the beginning, in order to make proper intervention when signs of noncooperation appear.

A class setting using group learning can activate students' motivation to learn. After they were divided into groups, students sensed that they were in the same boat with their teammates while learning. They then learned to compete as groups instead of as individuals. In Groups 1 to 4, students with lower grades had the chance to feel a sense of achievement; students with good grades became the motive force for their group members to learn because they took the responsibility to lead the group in sharing and improving; and those who cared nothing about grades tended to be influenced by their teammates and to identify more with their group's values. Thus, during the process of cooperative learning, iterated game and intergroup competition promote students' learning by cooperative activities.

Responses from the questionnaires show that cooperative learning can raise the level of students' interest in learning, make lessons more comprehensible, foster group membership and improve student academic performance. According to the students, learning cooperatively has the following advantages: they can discuss with teammates for better comprehension, urge one another to learn and pick up key learning points more easily. They also mention two disadvantages: when a group member does not cooperate, the group score is pulled down, also students found it troublesome to move desks and chairs in order to learn in groups. It is only through cooperation that group performance and individual scores improve, and when cooperation fails to happen, little improvement can be seen. Thus, if individual scores relate only to personal efforts, the goal of letting students learn cooperatively will not be reached at all.

5. Conclusions

The result of the study showed that cooperative learning has significant effects on performances. Students in the class that emphasized cooperative learning performed remarkably better than students in other classes. When the comparison is taken within the cooperative learning class, students in cooperative groups have better performances than students in non-cooperative groups.

In cooperative learning groups, students with lower records of academic performance achieved remarkable progress, while most students with higher academic records also showed noticeable progress as well. One possible explanation is that students with lower academic records are more likely to benefit directly from knowledge-exchanging activities such as group discussion. Students with higher records also have to practice and learn as they contribute to group discussion. One more reason for the elevation of performance could be that many students studied harder because they wanted to win peer recognition. The success of cooperative learning depends largely upon the students initial attitude towards group learning because positive feedbacks motivate students for cooperation, and negative feedback restrains cooperation in repeated rounds of evaluation.

Intergroup competition and iterated games were effective guidelines for promoting cooperative learning. The result showed that it was helpful for using game theory as the theoretical model for analysing cooperative learning in the classroom.

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