Using Game-Based Cooperative Learning to Improve Learning Motivation: A Study of Online Game Use in an Operating Systems Course

Article *in* IEEE Transactions on Education · May 2013

DOI: 10.1109/TE.2012.2207959

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***Abstract*—Many researchers have studied the use of game-based learning. Game-based learning takes many forms, including virtual reality, role playing, and performing tasks. For students to learn specific course content, it is important that the selected game be suited to the course. Thus far, no studies have investigated the use of game-based cooperative learning in an operating systems course. For this study, an online game was developed to enable students to learn cooperatively. The findings indicate that students' desire to win the game motivates them to learn from online course materials before they play, which in turn can enable them to achieve better learning outcomes.**

***Index Terms*—Cooperative learning, game-based learning, game questionnaire, learning achievement, learning motivation.**

I. INTRODUCTION

TRADITIONAL classroom teaching tends to be didactic. Therefore, when students do not find course materials interesting, they become less motivated to learn. In order to resolve this problem, many instructors employ teaching aids to augment the impact of the classroom period; game-based learning is one such tool. When instructors integrate course materials with the content of a game, and then allow students to play the game in class, the students acquire important knowledge through their gaming experience [1]–[3]. With advances in computer and network technology, many courses can now be held or supplemented online, and students can use their own computers to access course content on the Web. This makes it possible to use game-based learning in the development of learning technology [2]–[4] such that students are no longer confined to a classroom setting when learning. For example, it is possible to stimulate students' algorithmic thinking by asking them to program simulations in a game; in this way, they develop their ability to write efficient program code [5]. Some researchers also combine game-performing tasks with course content; by performing such tasks in a game setting, students acquire course-related knowledge step by step [2]. The work reported in this paper is based on such research. This study experiments with the use of games as a teaching aid in an Operating Systems course taught to juniors in the Department of Information and Computer Engineering, Chung Yuan Christian University, Taiwan. The purpose of the study is to improve student motivation, thereby helping students to achieve better learning outcomes.

The various units of the Operating Systems course are the following: computer system architecture, operating system architecture, processing unit, synchronization, CPU scheduling, deadlock, memory management, and file system management. Students in the course must also complete several course-related projects. Most find it difficult to master the course; in addition to memorizing essential course materials, they must tackle difficult concepts in computer system architecture, operating system architecture, memory management, and file system management. They also need to understand topics such as processing units, synchronization, and deadlock. Perhaps their most difficult task is to complete the course projects [6], which are related to CPU scheduling, memory management, and processing units. As a result of all these factors, students can become frustrated in their learning and often lose motivation as the course proceeds, causing many to give up the course. Therefore, in this study, an online learning game was developed and integrated with the Operating Systems course contents. Students' desire to win the game motivates them to study course-related materials before playing. When they win rounds of the game, they become even more motivated and, as a result, they achieve better learning outcomes.

II. RELATED WORK

A. Game-Based Learning

In game-based learning, course content is presented to learners while they are engaged in game playing. The primary goal of this approach is to improve learner motivation [4]. The game itself is not the main focus of the course; its use is only part of the teaching strategy. For example, educational games can be integrated with cooperative learning [7]. When students are shown an abundance of colorful screen designs coupled with sound effects and instructional materials, they are motivated to learn, and they learn better. Researchers have applied game-based learning in a variety of educational settings [2], [8], [9]. For example, "Re-Mission" is used to help

Manuscript received February 24, 2012; revised May 10, 2012; accepted June 25, 2012. Date of publication July 18, 2012; date of current version May 01, 2013.

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Digital Object Identifier 10.1109/TE.2012.2207959

patients understand cancers in medical therapy [10], the "Chief Knowledge Officer (CKO)" is used to teach students about knowledge management [11], and "River City" is used to teach environmental science [12].

Several characteristics of game-based learning have been identified [13].

- By participating in games, students are motivated to review the knowledge they have just acquired.
- The instant feedback provided by the gaming environment allows instructors to see the progress of individual students and give suitable suggestions in a timely manner.
- Through game playing, students can exchange knowledge with one another.
- Game playing enables students to learn in an informal way, so that they do not feel bored.
- Game playing is often accompanied by discussions and social activities.

B. Cooperative Learning

Cooperative learning emphasizes mutual dependency and cooperation; in performing each learning task, group members work together to achieve the same learning goal. There are different notions of cooperative learning; cooperative learning groups were have been formed in various ways. Despite this, the general consensus is one of group discussion, member interaction, and peer assistance [14]. Compared to individual learning and competitive learning, cooperative learning is better in raising the level of learning achievement for students; it also helps to improve both the learning motivation and the cooperation skills of students [15]. In addition, group discussion stimulates deep thinking [16]. To make cooperative learning more effective, there are important elements to consider [17]. To start with, students should realize the importance of cooperatively achieving the learning goals. Second, assessment should include how students divide their tasks, share resources, take responsibilities, and work together. Third, students should engage in discussion with, and provide assistance to, each other. By fulfilling their roles, they gain a sense of responsibility. Finally, the instructor should always provide appropriate assistance when needed.

C. Game-Based Learning by Digital Design

Motivation is crucial for learning. When learners have low motivation, they may not learn at all despite participating in learning activities. Researchers can add the element of game playing to a course to increase learners' motivation and attract their attention, thereby helping them focus [18]. It is not easy to design a game that is both integrated with existing course contents and interesting. Echeverria *et al.* [19] propose a design methodology for integrating the characteristics of a game with the various elements of a course. They identify the various elements of games and course contents: a Ludic Dimension is the set of elements of a game, whereas an Educational Dimension is the set of elements of a course [19]. The integration of the Ludic and Educational Dimensions combines mechanics with cognitive processes, type of knowledge, pedagogical model, and story.

To include game playing in learning activities, instructors should consider the nature and content of the course and who their students are. For example, students of different age levels have different game preferences. Primary school students may like single-player games. For them, playing simple task-performing games and performing better than their classmates can bring about a sense of achievement [20], [21]. High school students prefer games with an abundance of video images and sound effects. Apart from their requirement for systematic scenarios, they also have higher expectations for software quality [2]. College students, on the other hand, prefer multi-player online games in which they can interact with others.

The content of such games evolves according to the manner in which the players interact [22]. Past works on game-based learning have focused mainly on primary and high school courses [23], but rarely on college courses. For college students, a game has to have a reasonable degree of sophistication to be "playable." Therefore, the principal issue here is how game-based learning can be designed to improve college students' learning motivation, thereby helping them achieve better learning outcomes. This study develops a peer interaction game with a competitive cooperative learning style and integrates the game with the course content. By playing the game, students participate in a group process; members of the same group coordinate, discuss, and share their thoughts, whereas different groups compete with one another. From the perspective of course nature and content, the Operating Systems course requires programming practices, along with concept understanding and memorization. It is generally considered a boring course, and many of the students who enroll have low motivation. Therefore, there is a strong incentive to include game-based learning in the teaching of this course.

III. Peer Interaction Game

A. Game Method

The study described here develops a peer interaction game for six players. The players are divided into two competing three-person teams. A team size of three persons was selected so that every team member can be fully involved. It also makes it possible for skills to be used at appropriate times and ensures that the game does not take too long to complete. This design accords with Lou *et al.* [24], who suggest that the best arrangement is to have three to four persons per team. This also ensures that the game-playing system provides adequate room for all players to participate.

Students log in to the game online. Once they are logged in, each team of three must decide who will play which role, with each player taking one role. When all six players have chosen their roles, the game automatically begins. Different roles correspond to different professions, and each profession has its own set of attributes and skills. For example, the main skill of a warrior is to attack. The design of this role emphasizes the amount of blood loss for each attack, as Fig. 1 shows. In contrast, the wizard's role emphasizes assisting team members, as Fig. 2 shows. Lastly, the main emphasis of the archer is on helping team members attack opponents more effectively. Therefore, in the design of this role, emphasis is placed on controlling the time

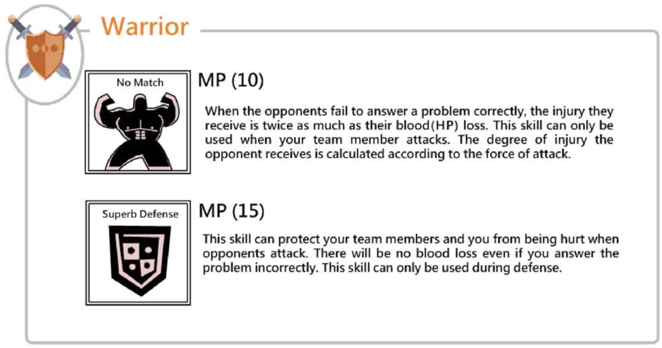

Fig. 1. Warrior skills.

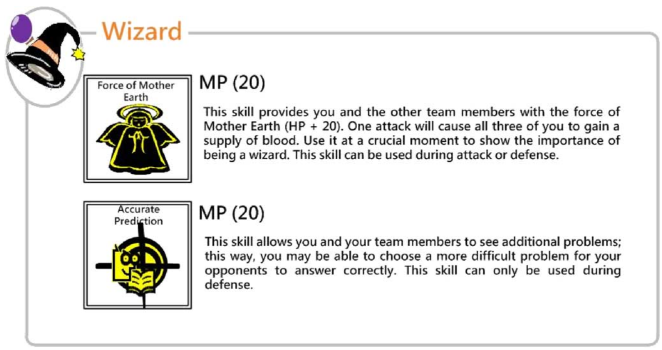

Fig. 2. Wizard skills.

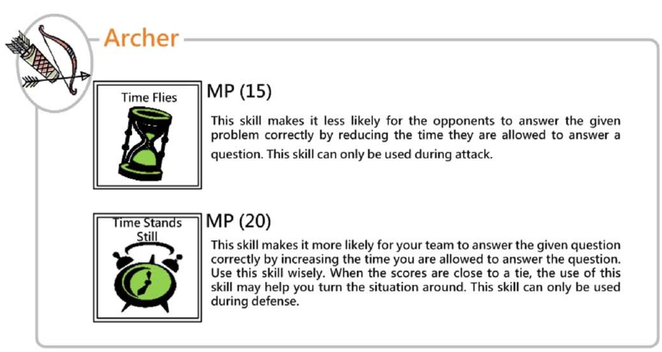

Fig. 3. Archer skills.

for answering questions, as shown in Fig. 3. Assigning different attributes to each role means that students can not only hold discussions via the Web, but also make use of the different skills to dramatically increase their interest in playing the game. This results in a better learning effect.

Fig. 4 presents a snapshot of the gaming interface. The two participating teams are labeled as the Union and the Tribe. As the game starts, the system randomly decides whether it is the Union's or the Tribe's turn to attack. The game is played round by round. Assume that it is the Union that attacks and the Tribe that defends. Then, one Union team member chooses a question for a Tribe team member to answer. Subsequently, a Tribe team member chooses a question for a Union team member to answer. Fig. 5 presents this question and answer sequence. The questions used are multiple-choice, and each has its own time limit. Each player can use the skills associated with his/her role

Fig. 4. Game interface.

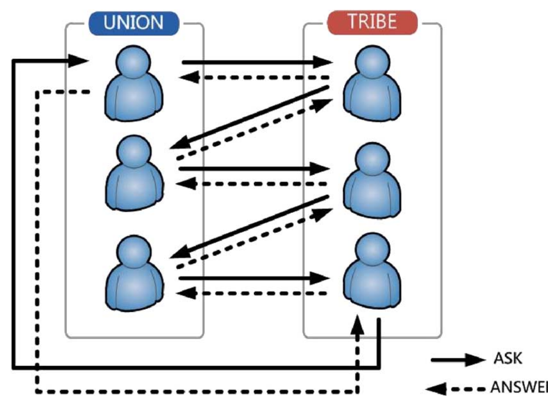

Fig. 5. Game sequence.

to improve the effect of attack or defense for his/her team. The use of a skill by a player always costs some magic point (MP) value.

As they play, all players can see the full set of available game questions listed in the Candidate Question Area of the center of Fig. 4. Within a prespecified time limit, the attack team can discuss which question they want to use for their attack, and the defense team can discuss which one they will select in the next round. They do this in the area titled "Discussion with the group" (Fig. 4, lower left). Once the attack team has selected the "attack question," members of the defense team can see it in their Question-to-Answer areas, and the answer choices will appear in their Answers-to-Question areas. However, only the designated defender can answer the question. The other two members of the defense team can only discuss the answer choice with the designated defender. Once the designated defender has selected an answer, the system checks it for correctness. If the answer is correct, the blood level of the attack team is lowered. If the answer is incorrect, the blood level [health point (HP) value] of the defense team is lowered. If the blood level of a player reaches zero, that player is forced to retire from the game and he/she will no longer be able to use his/her skills or participate in the discussions. When the blood levels of all three players on a team reach zero, the game is over.

The peer interaction game used in this research encourages team members to cooperate with one another when competing with another team. By incorporating competition, the game motivates participants to win. Moreover, by providing a means for team members to discuss a question posed to any one of them, the game allows the other two team members to provide timely assistance. These factors—cooperation, competition, and different skills attributed to different roles—are what make the game appealing to students.

The peer interaction game used in this study is specifically designed for students in the Operating Systems course. Its most important characteristic is peer interaction, followed by the design of skill sets assigned to different player roles and the effects of using these skills in game playing. Consider peer interaction, for example. Teammates discuss which attack questions to choose, as well as answers to questions assigned to them by the opponent; they also discuss which skills they should use and when, according to whether they believe their answer to a question is correct and whether their opponent will encounter difficulties in answering an attack question. When players use a skill at the appropriate time, their likelihood of winning the game increases. For example, when a player attacks the opposing team's wizard, the player's teammate who is playing the warrior role can use his/her "No Match" skill to decrease the blood level of the wizard to zero. In this manner, the wizard will not be able to use his/her skill to supply more blood to his/her team. Thus, using the different skills provided in the game allows for various ways of playing, which makes the game much more fun for learners.

B. *Design Rationale of the Peer Interaction Game*

In this study, the design rationale of the game is based on the architecture proposed by Echeverria *et al.* [19], which combines elements of the game with those of the course. Table I contrasts the game design with the design principles proposed by Echeverria *et al.* Table II explains the various characteristics of the peer interaction game.

TABLE I
GAME DESIGN CONFORMS TO ECHEVERRIA *et al.* [19]

	Peer interaction game
Mechanics associated with cognitive processes	
Remember	Students may be asked questions that were previously answered incorrectly. If the students do not discuss their answers to such questions, they reduce their chance of winning.
Understand	Students discuss questions with their peers. They learn more about the course contents through this process.
Apply	Students acquire knowledge of operating system principles by playing the game. This helps them with assigned homework and projects.
Analyze	Students hold discussions with their peers to select the right answer to the given question.
Evaluate	When playing, students can provide feedback about the level of difficulty of the questions as well as the pitfalls of the game.
Create	Students choose different roles to play and make use of the different skills assigned to each role to play the game differently.
Mechanics associated with type of knowledge	
Factual	The questions and their corresponding answers are clear. Students can easily locate the questions and their answers in course materials.
Conceptual	There are several concepts for every round of the game. Questions testing the same concept are placed together. Therefore, students can clearly identify the concept being tested by each question.
Procedural	Students choose attack problems as well as their answers to the given questions. They discuss and review the relevant knowledge.
Meta-cognitive	Students play this game several times in the same semester. They must find the best way to win. The more a team wins, the more points they are awarded.
Mechanics associated with pedagogical model	
	Students must help their teammates in order to win. Therefore, they must communicate about which attack problem to use and coordinate the use of their skills. After playing the game for one semester, the winning team will receive a good score, which is their reward.
Story associated with pedagogical model	
	The peer interaction game is played several times over the course of the semester. Students are given different questions to choose from according to the progress of the course. These questions reflect relevant course materials taught at the time the game is played.

IV. EXPERIMENTS

A. *Participants*

In this experiment, the participants were 128 students enrolled in the Department of Information and Computer Engineering, Chung Yuan Christian University. The participants took the Operating Systems course in the Spring semester of 2011. The two classes of this course naturally became the experimental group and the control group, with 63 participants in the experimental group and 65 in the control group. The participants' learning motivation, process, and achievement were evaluated both before and after the experiment. A learning motivation questionnaire was used to assess the change in motivation. The MSLQ used by Pintrich *et al.* [25] assesses three dimensions of learner attitude and includes 31 questions. Wilke [26] indicates that only the first dimension of attitude pertains to learner motivation. Therefore, only 14 questions relevant to the assessment of learner motivation were included in the questionnaire used in this study. It was very difficult to obtain offline learning records. Therefore, a learning feedback form (Table III) was used to ask the participants about their learning processes. From this feedback form, and by retrieving learning portfolios recorded online, it was possible to assess the learning processes of the participants. Pretest and post-test were performed to assess the participants' learning achievements. An additional questionnaire was used to ask the participants whether they considered the game attractive and how they evaluated it. There were 12 questions in this questionnaire (Table IV).

B. *Procedure*

The experiment lasted eight weeks. The 63 participants in the experimental group were randomly divided into 21 groups, with three participants in each group, and the 65 participants of the control group were randomly divided into 22 groups, with one group containing only two participants.

There were three kinds of learning activities for the experimental group: didactic teaching, asynchronous e-learning, and peer interaction games. The control group did not participate in

TABLE II
CHARACTERISTICS OF THE PEER INTERACTION GAME

Characteristics	Explanation
Mechanics	When a student plays a different role in the game, he/she is assigned different attributes and skills. Therefore, each student can choose the role that is most suited to him/her. The players take turns asking and answering questions. Teamwork is essential to winning the game. Teammates must discuss and decide on their answer to the assigned question, the most appropriate problem to use for an attack, and the most appropriate skill to use and the timing of its use.
Story	Each student plays a different role in the game, and each team sees a different question, along with its possible answers, during each round of the game. The roles the students play affect how the game proceeds. By choosing the roles appropriately, players increase their likelihood of winning. They can try different combinations of roles each time they play and vary their use of skills in the game context. By appropriately coordinating role assignment and the strategic use of skills, players can find the best possible combination for the team.
Technology	The game uses pictorial changes for visual effects. The discussion area operates in real time, allowing all teammates to participate in the discussions. Course contents are blended into the progress of the game by requiring players to select and answer attack questions.
Aesthetics	Every role has a specially assigned picture for the students to recognize. No sound effects are provided in order to not interfere with team discussions. The screen background is set to one color so that players can concentrate on the text during discussions.

TABLE III
EXPLANATION OF THE FEEDBACK RESULTS

Question	Explanation of feedback
How many hours per week did you spend studying for this course?	Members of the experimental group spent about three hours and forty minutes per week studying for Operating Systems. Members of the control group spent about three hours and fifteen minutes per week studying. This suggests that members of the experimental group spent slightly more time learning.
How many hours per week did you spend discussing the course contents with your peers?	Members of the experimental group spent about one hour and thirty minutes per week discussing the course contents with peers. Members of the control group spent about one hour and twenty minutes per week on discussions. This suggests that members of the experimental group spent slightly more time an discussions.
How many hours per week did you spend doing homework or projects for this course?	Members of the experimental group spent about two hours and thirty minutes per week on homework and projects. Members of the control group spent about one hour and forty minutes per week on the same thing. Comparatively, members of the control group spent much less time on doing homework and projects.

the peer interaction game; they went through traditional cooperative learning instead. Figs. 6 and 7 present the experimental procedure for the experimental and control groups, respectively. The procedure comprised six stages. Stage 1 was the pretest: Both groups took an exam and answered the learning motivation questionnaire. No significant differences were found between the two groups. Stage 2 consisted of cooperative learning. The experimental group engaged in cooperative learning by playing the peer interaction game, whereas the control group did so in the more traditional way, that is, face-to-face. Both groups used the same set of questions designed by the instructor. All questions were multiple-choice. In Stage 3, the same learning motivation questionnaire was administered to determine whether

TABLE IV
RESULTS OF THE GAME QUESTIONNAIRE

No.	Questionnaire	Agreement rated on a seven-point scale (average)
1	I am satisfied with the pictures used in the game.	4.74
2	If there were more visual effects in the game, I would get even more involved.	5.59
3	If there were more audio effects in the game, I would get even more involved.	5.48
4	All questions in the game were stated clearly.	4.54
5	I maintained good interaction with my teammates.	5.78
6	The way we interacted in the game helped me to learn.	5.63
7	I actively participated in discussions when playing the game.	5.70
8	I am satisfied with the way interaction happened in the game.	5.52
9	After playing this game, I have become more willing to learn about operating systems.	5.46
10	It was quite pleasant to win this game.	6.07
11	I like this game.	5.67
12	I would recommend this game to freshmen and sophomores in our department.	5.52

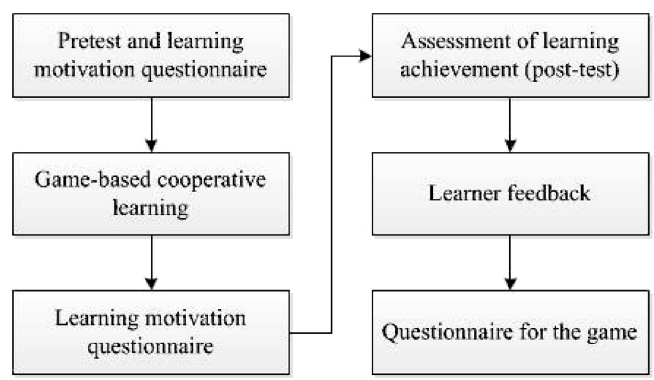

Fig. 6. Experiment procedure for the experimental group.

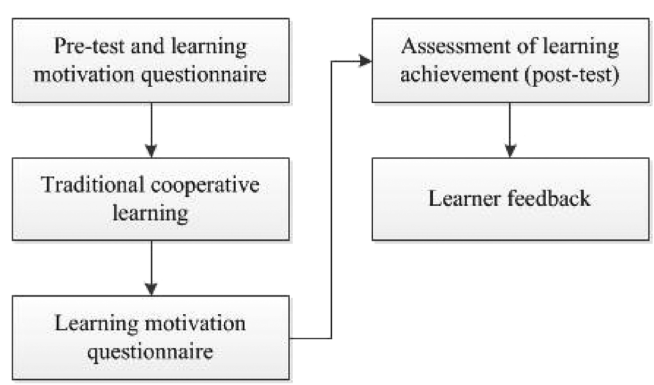

Fig. 7. Experiment procedure for the control group.

there was a significant difference in learner motivation. Stage 4 was the post-test. Both groups retook the exam that they had taken in Stage 1 as a measure of their learning achievements. The set of questions used in the pretest was redesigned for the post-test, so that members of the experimental group could not benefit from viewing more of the questions used in Stage 2. In

TABLE V
ANOVA OF LEARNING QUESTIONNAIRE RESULTS

Stage	Group	Average	Variance	F	Critical value	α
Stage 1	Experimental	55.325	335.4045	1.00531	3.963471	0.05
	Control	59.575	383.2763			
Stage 3	Experimental	74.1	172.5538	5.33351	3.963471	0.05
	Control	67.475	156.6147			

TABLE VI
ANOVA OF PRETEST AND POSTTEST RESULTS

Stage	Group	Average	Variance	F	Critical value	α
Pretest	Experimental	55.325	335.4045	1.00531	3.963471	0.05
	Control	59.575	383.2763			
Posttest	Experimental	58.55	231.1769	9.00836	3.963471	0.05
	Control	46.15	451.5666			

the test, there were multiple-choice questions as well as problems that required answers. In Stage 5, all the participants completed a learning feedback form, and their online learning performances were calculated. In Stage 6, only the experimental group filled out a questionnaire for the game.

As a result, the following data were collected: learning motivation questionnaire results from Stages 1 and 3, pretest and post-test scores, online performance scores, learner feedback, and questionnaire results for the game. After participants who dropped out of the course or who did not participate in some of the tests or questionnaires were excluded, 41 participants remained in the experimental group and 40 in the control group. The data collected for these 81 participants were subsequently analyzed.

C. Data Analysis

Table V presents the ANOVA of learning motivation questionnaire results. In Stage 1, the F-value is no greater than the critical value. This means that before the cooperative learning activities, there was no significant difference in learning motivation between the two groups. In Stage 3, the F-value is greater than the critical value. This means that after members of the experimental group participated in game-based cooperative learning, their learning motivation significantly increased; as a result, there was a significant difference in learning motivation between the groups. This finding indicates that the game-based cooperative learning used in the study is more effective than traditional face-to-face cooperative learning for improving learning motivation.

Table VI presents the ANOVA of pretest and post-test results. For the pretest result, the F-value is not greater than the critical value, which means that there was no significant difference in learning achievement between the experimental and control groups. For the post-test result, the F-value is greater than the critical value, which means that there was a significant difference in learning achievement. This, in turn, means that students who participated in game-based cooperative learning achieved more when compared to those who participated in traditional face-to-face cooperative learning.

When students learn online, their learning activities can be recorded in portfolios [27]. Translating these learner records

TABLE VII
WEIGHTS OF THE EIGHT ONLINE BEHAVIOR ITEMS

Item	Weight (in percentage)
Total number of logins	15.7
Number of days logins occur	15.99
Number of course discussion posts	8.8
Number of special topic posts	6.26
Number of clicks related to course discussions	15.72
Hours spent studying course materials	16.32
Number of clicks related to special topic discussions	7.75
Number of clicks related to course discussions	13.46
Total	100

TABLE VIII
ANOVA OF STUDENTS' ONLINE PERFORMANCE SCORES

Stage	Group	Average	Variance	F	Critical value	α
Pretest	Experimental	51.45	426.8179	1.50579	3.963471	0.05
	Control	46.125	326.4198			
Posttest	Experimental	54.675	302.4301	4.70566	3.963471	0.05
	Control	46.35	286.6948			

into overall online performance scores can help instructors understand how individual students perform online. In the past, instructors have had to define a weight for each item of online behavior period. However, the resulting scoring scheme may be too objective and may not correspond to real learner situations.

Li [27] suggests a method for computing overall online performance scores based on Principal component analysis [28], [29]. Principal component analysis redistributes the weights of all attributes and makes the attributes as independent as possible. It is therefore suitable for revealing differences between the attributes.

In this study, eight online behavior items were considered: total number of logins, number of days logins occur, number of course discussion posts, number of special topic posts, number of clicks as related to course materials, hours spent studying course materials, number of clicks related to course discussions, and number of clicks related to special topic discussions. These items were automatically recorded by the system when students accessed the e-learning platform. Li's method is used to transform each student's online behaviors into an overall online performance score. Table VII presents the weights for these eight items.

The students' online performance scores were computed and analyzed to see whether they performed better in learning activities when they participated in game-based cooperative learning. First, the students' overall online performance scores were computed for System Programming (a required course taught by the same instructor during the Fall of 2010); these scores served as the pretest. Then, the overall online performance scores from the experiment were computed; these served as the post-test. Table VIII presents the two ANOVA results of these scores. As the table shows, there is no significant difference in the pretest scores between the groups. However, the post-test scores show a significant difference, suggesting that the use of game-based cooperative learning is superior to traditional face-to-face cooperative learning with regard to stimulating students' online learning activities.

TABLE IX
SUMMARY OF LEARNER FEEDBACK

Group	Number of participants	Hours per week spent studying for the course	Hours per week spent on discussions with peers	Hours per week spent on homework and projects
Experimental	41	03:40	01:34	02:34
Control	40	03:15	01:19	01:43

TABLE X
STUDENT FEEDBACK ON LEARNING STRATEGIES

Control group	Experimental group
First, finish viewing the pre-recorded class videotape at home. Then, participate in the in-class discussion to fill in gaps in understanding the concepts. Finally, review the instructor's class notes.	Before attending each class, always finish viewing the relevant class videotape at home. Often, view more videotapes than are required. Take time to do homework and tests. Visit the discussion board at fixed intervals. Answer questions on the board if necessary.
Study before taking the exam.	View a part of the pre-recorded class videotapes before going to class. Occasionally, take a look at the discussion board. Moreover, review class materials before playing the peer interaction game. Always do the homework and projects without copying others' work. Always try to see what the answers should be after taking the exam.
Attempt to finish viewing all pre-recorded class videotapes in just a few days.	Review course contents before doing homework and projects. Read the textbook before attending each lab session.

In Stage 5 of the experiment, students filled out feedback forms. Table IX presents a summary of the results. Table III gives an explanation of the results.

Table IX shows that members of the experimental group spent more time on learning activities as compared to their control group counterparts. This suggests that game-based cooperative learning provides further stimulus for learning. As it happened, the instructor of this course also gave students the chance to make up their homework at the end of Spring 2011. Table IX shows that members of the experimental group were much more aggressive than their control group counterparts in taking advantage of this chance.

In addition, when asked to describe how they learned for the course, members of the two groups gave different answers. Table X shows that members of the experimental group displayed a more positive learning attitude. In contrast, members of the control group were not so uniform in terms of their learning attitudes. Some learned actively, some passively, and some even failed to keep up with the course. Overall, the findings indicate that game-based cooperative learning provides a better stimulus for learning than does traditional face-to-face cooperative learning.

After the experiment concluded, members of the experimental group were given a questionnaire. A total of 46 questionnaire results were collected. A reliability analysis of these 46 questionnaire results found a Cronbach's alpha value of 0.900. Table IV presents the results of the game questionnaire. It shows that students had good interactions with their peers during the game and were satisfied with these interactions. The students also agreed that their interactions with the game helped them to learn. This suggests that the game motivated them to learn more. Overall, the students were interested in the game and indicated that they would recommend it to other students in the department. Moreover, students highly agreed that they found it pleasant to win. This means that winning the game can give students a sense of confidence and achievement, and it motivates them to learn more about operating systems. The students also expressed that they were not satisfied with the visual and sound effects of the game, but were otherwise satisfied with how the questions were presented.

V. CONCLUSION AND FUTURE STUDY

The goals of this research were to do the following.

— Develop a game integrated with the course content of, and use it in teaching, the Operating Systems course. In playing this game, team members cooperate with one another to compete with another team.
— Evaluate whether the use of peer interaction games improves student learning motivation, performance, and/or learning outcomes.
— Analyze the extent to which students are satisfied with this pedagogy.

To that end, this study investigated the differences in motivation, achievement, and activities between game-based cooperative learning and traditional face-to-face cooperative learning. It was found that game-based cooperative learning excels in all these aspects. Therefore, the kind of online, multiplayer, game-based cooperative learning used in this research is effective for improving learning achievement, and it has a positive effect on the learning process as well.

The following qualitative observations were made regarding the process of cooperative learning in the two groups. Driven by the desire to win (Table IV, Item 10) students participating in game-based cooperative learning try to find answers through online group discussions whenever they are being "attacked" by questions with which they are unfamiliar; they also carefully plan the use of the skills to maximize their chances of winning. Even if the answers they give are wrong, they continue playing the game, and they are more likely to study unfamiliar course content afterwards. In contrast, students participating in the traditional face-to-face cooperative learning tend to rely on the more capable students in answering the given questions. The activity easily becomes centralized learning, with only the more capable students actually participating. Those who rely on the more capable students tend not to realize that they lack the necessary knowledge, and they are less likely to study more in private.

This seems to be the reason why members of the experimental group spent more time on various learning activities (Tables VIII and X). It also explains why they learned more in general (Table VI).

There are also some conclusions that can be drawn from the participant feedback. Since members of the experimental group were more willing to spend time on learning activities, this shows that game-based cooperative learning can stimulate active learning. Many control group members relied on others to answer questions. Therefore, it is only natural for these students to be less active in learning.

In the future, the goal is to apply game-based cooperative learning in different courses and for various types of participants in order to gain a broader understanding of the applicability of this pedagogy.

Future versions of the game should improve the visual and sound effects. More dynamic pictures and skills can be added as well to further motivate the students to play.

REFERENCES

[1] B. D. Coller and M. J. Scott, “Effectiveness of using a video game to teach a course in mechanical engineering,” *Comput. Educ.*, vol. 53, no. 3, pp. 900–912, 2009.

[2] M. Papastergiou, “Digital game-based learning in high school computer science education: Impact on educational effectiveness and student motivation,” *Comput. Educ.*, vol. 52, no. 1, pp. 1–12, 2009.

[3] J. Robertson and C. Howells, “Computer game design: Opportunities for successful learning,” *Comput. Educ.*, vol. 50, no. 2, pp. 559–578, 2008.

[4] N. Vos, H. Van Der Meijden, and E. Denessen, “Effects of constructing versus playing an educational game on student motivation and deep learning strategy use,” *Comput. Educ.*, vol. 56, no. 1, pp. 127–137, 2011.

[5] H. C. Jiau, J. C. Chen, and K. F. Ssu, “Enhancing self-motivation in learning programming using game-based simulation and metrics,” *IEEE Trans. Educ.*, vol. 52, no. 4, pp. 555–562, Nov. 2009.

[6] M. McCracken, V. Almstrum, D. Diaz, M. Guzdial, D. Hagan, Y. B.-D. Kolikant, C. Laxer, L. Thomas, I. Utting, and T. Wilusz, “A multi-national, multi-institutional study of assessment of programming skills of first-year CS students,” *ACM SIGCSE Bull.*, vol. 33, no. 4, pp. 125–180, 2001.

[7] T. Hainey, T. M. Connolly, M. Stansfield, and E. A. Boyle, “Evaluation of a game to teach requirements collection and analysis in software engineering at tertiary education level,” *Comput. Educ.*, vol. 56, no. 1, pp. 21–35, 2011.

[8] E. Y. Leng, W. Z. W. Ali, R. Mahmud, and R. Baki, “Computer games development experience and appreciative learning approach for creative process enhancement,” *Comput. Educ.*, vol. 55, no. 3, pp. 1131–1144, 2010.

[9] L. M. Miller, C. I. Chang, S. Wang, M. E. Beier, and Y. Klisch, “Learning and motivational impacts of a multimedia science game,” *Comput.Educ.*, vol. 57, no. 1, pp. 1425–1433, 2011.

[10] I. L. Beale, P. M. Kato, V. M. Marin-Bowling, N. Guthrie, and S. W. Cole, “Improvement in cancer-related knowledge following use of a psychoeducational video game for adolescents and young adults with cancer,” *J. Adolescent Health*, vol. 41, no. 3, pp. 263–270, 2007.

[11] A. Y. K. Chua, “The design and implementation of a simulation game for teaching knowledge management,” *J. Amer. Soc. Inf. Sci. Technol.*, vol. 56, no. 11, pp. 1207–1216, 2005.

[12] B. C. Nelson, “Exploring the use of individualized reflective guidance in and educational multiuser virtual environment,” *J. Sci. Educ. Technol.*, vol. 16, no. 1, pp. 83–97, 2007.

[13] D. J. Ketelhut and C. C. Schifter, “Teachers and game-based learning: Improving understanding of how to increase efficacy of adoption,” *Comput. Educ.*, vol. 56, no. 2, pp. 539–546, 2011.

[14] R. M. Gillies and A. F. Ashman, “The effects of training in cooperative learning on differential student behavior and achievement,” *J. Classroom Interact.*, vol. 32, no. 1, pp. 1–9, 1997.

[15] M. Pérez Cereijo, “Attitude as predictor of success in online training,” *Int. J. E-Learning*, vol. 5, no. 4, pp. 623–639, 2006.

[16] J. E. Marshall, “Effects of cooperative incentives and heterogeneous arrangement on achievement and interaction of cooperative learning group in a college life science course,” *J. Res. Sci. Teach.*, vol. 32, no. 3, p. 2991-299, 1995.

[17] D. W. Johnson and R. T. Johnson, “Cooperative learning,” in *The Effective Teacher*, L. W. Anderson, Ed. New York: Random House, 1989.

[18] K. M. Y. Law, V. C. S. Lee, and Y. T. Yu, “Learning motivation in e-learning facilitated computer programming courses,” *Comput. Educ.*, vol. 55, no. 1, pp. 218–228, 2010.

[19] A. Echeverria, C. Garcia-Campo, M. Nussbaum, F. Gil, M. Villalta, M. Amestica, and S. Echeverria, “A framework for the design and integration of collaborative classroom games,” *Comput. Educ.*, vol. 57, no. 1, pp. 1127–1136, 2011.

[20] Y. S. Chiang, C. Y. Liang, and H. Y. Chang, “Integrating factors of online game stickiness and e-learning continuity to develop game-based learning materialism,” *Instruct. Technol. Media*, vol. 83, pp. 61–76, 2008.

[21] S. W. Liu and H. Y. Hsu, “Design guidelines of motivational strategies for K-9 multimedia course development,” in *Proc. ICCAI*, Taipei, Taiwan, 2003, pp. 24–26.

[22] F. L. Fu, R. C. Su, and S. C. Yu, “EGameFlow: A scale to measure learners’ enjoyment of e-learning games,” *Comput. Educ.*, vol. 52, pp. 101–112, 2009.

[23] S. Suh, S. W. Kim, and N. J. Kim, “Effectiveness of MMORPG-based instruction in elementary English education in Korea,” *J. Comput. Assist. Learning*, vol. 26, no. 5, pp. 370–378, 2010.

[24] Y. Lou, P. C. Abrami, J. C. Spence, C. Poulsen, B. Chambers, and S. d’Apollonia, “Within-class grouping: A meta-analysis,” *Rev. Educ. Res.*, vol. 66, no. 4, pp. 423–458, 1996.

[25] P. R. Pintrich, D. A. F. Smith, T. Garcia, and W. J. McKeachie, “A manual for the use of the Motivated Strategies for Learning Questionnaire (MSLQ),” NCRIPTAL, School of Education, The University Michigan, Ann Arbor, MI, 1989.

[26] R. R. Wilke, “The effect of active learning on student characteristics in a human physiology course for nonmajors,” *Adv. Physiol. Educ.*, vol. 27, no. 1–4, pp. 207–223, 2003.

[27] C. Y. Li, “Applying learning portfolios to multiple adaptive remedial learning,” Master’s thesis, Chung Yuan Christian University, Taiwan, 2008.

[28] H. Hotelling, “Analysis of a complex of statistical variables into principal components,” *J. Educ. Psychol.*, vol. 24, no. 6, pp. 417–441, 1933.

[29] K. Pearson, “On lines and planes of closest fit to systems of points in space,” *Philos. Mag.*, vol. 2, pp. 559–572, 1901.

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