Comparing Competitive and Cooperative Strategies for Learning Project Management

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ABSTRACT

Many organizations use project management to organize and administer resources in time and in place in an effort to optimize costs and meet certain constraints. These constitute cognitive skills acquired through training and experience that have successfully been shown to be trainable through simulation. However, past research on simulation-based project management training focused on individual learning. In this paper, we are interested in investigating whether a competitive or cooperative strategy is more desirable in using simulators for project management training. Several theories suggest that cooperative learning is more beneficial to learning than competitive learning. To investigate this problem, an experiment was set up based on the simulation-based Project Management Trainer (PMT) software. The results suggest that using both PMT cooperative and competitive strategies yield learning in project management. However, cooperative strategies yield better results in the overall outcome.

Keywords: competition, cooperation, learning

I. INTRODUCTION

Project management is the discipline of organizing and managing resources in such a way that these resources do all the work required to complete a project within defined scope, time, and cost constraints. The first challenge of project management is to ensure that a project is delivered within a set of defined constraints. The next step is to optimize the allocation and integrate the inputs needed to meet those pre-defined requirements. Project management is a complex task and requires varying technical skills and philosophy.

The learning process for complex tasks such as project management may be characterized by a variety of factors and effects. Project management tasks can be defined as "pure" cognitive tasks. For each project, management complexity differs and corresponding decisions may change in compliance with the basic project management models. The use of simulation is a recent trend in engineering education. With the advent in computer technologies, and hence cheaper computing power, simulation provides students some hands-on experiences at a low cost (Feisel and Rosa, 2005). Simulation has been shown to be a useful tool in training for project management (Parush, Davidovitz, and Shtub, 2006; Davidovitch, Parush, and Shtub, 2007). However, the best way to train for project management using simulation remains unclear.

Psychologists (e.g., Johnson et al., 1981; Slavin, 1990) have suggested several benefits of using cooperative learning over competitive learning in a classroom. A cooperative structure is defined as having every group member rewarded on the basis of the quality of the group's product. In addition, with inter-group competition, the cooperative structure may give peer pressure within a group to maximize individual performance (Slavin, 1986). Common elements of cooperative learning methods include: (1) classes are divided into small groups with two to six members; (2) groups have an interdependent structure with high individual accountability; (3) the group objectives are clearly specified and defined; and (4) group members support each other's efforts to achieve (Kluge 1990). Competitive learning is based on a competitive goal structure in which an individual can attain his or her goal if the other participants cannot attain their goals (Deutsch, 1949). A number of experiments were set up to compare cooperative learning and competitive learning. There was no strong quantitative evidence showing that one was superior to the other in the results. The participants of the experiments, however, reported their preference toward cooperative learning. In this study, we define *competitive learning* in a somewhat broader sense to include norm-referenced criteria. That is, participants can compete directly for resources or less directly in terms of rewards for eventual performance. This definition is consistent with many of those in the literature, (e.g., Covington and Omelich, 1984; Johnson, Johnson, and Stanne, 1986; Campbell and Furrer, 1995). We further remark that competitive learning differs from common definitions of *individualistic learning*, where both the activities and the goals are obtained independently (Johnson, Johnson, and Stanne, 1986).

Sherman (1986) investigated and compared cooperative and competitive learning in introductory educational psychology. Four different introductory education psychology course sections were taught. Three of the four had a cooperative goal structure (two without intergroup competition, one with intergroup competition), and one had an individual goal structure. The results showed no significant differences in achievements among the four groups.

Qin, Johnson, and Johnson (1995) studied the impact of cooperative and competitive efforts on problem solving. At least 46 individual studies on the topic, which were published between 1929 and 1993, resulted in 63 specific conclusions that were classified into four categories according to the type of problem: linguistic (problems solved through written and oral language), nonlinguistic (problem solved through symbols, math, motor activities, actions), well-defined (problems have clearly defined operations and solutions), and ill-defined (problems do not have clear definition, operations, and solutions). Out of the 63 findings, 55 were in favor of cooperation, while eight found that competition outperformed cooperation. While these studies generally supported the idea that cooperative learning outperforms competitive learning in each of the four categories regardless of the level of difficulty of the problem and the age of the participants, the preference toward cooperative learning over competitive learning was not particularly strong. Out of the four categories of problems, cooperative learning outperformed competitive learning more significantly in nonlinguistic and ill-defined problems.

Johnson et al. (1981) conducted a meta-analysis on the effect of cooperative and competitive goal structures on performance, wherein 122 studies conducted in North America were reviewed. There were 4 goal structures: cooperation, cooperation with intergroup competition, interpersonal competition, and individualistic efforts. Three methods of meta-analysis were used: the voting method, the effect-size method, and the z-score method. The results showed that there was no real difference in performance between cooperation with intergroup competition and cooperation without intergroup competition, while cooperation promoted higher performance than competition did. As for the comparison between cooperative with intergroup competition and interpersonal competition, cooperation with intergroup competition showed some benefits over interpersonal competition.

With this as background, we remark that the balance of the research literature supports the idea that there may be a general preference for cooperative learning, while some questions remain for applying this to learning project management. Namely, is a cooperative system nonetheless preferred in this environment? That is, does a cooperative structure yield greater learning, and/or improved individual performance? Thus, the objective of this paper is to investigate whether cooperative or competitive learning performs better for simulation-based project management training. We hypothesize that (1) cooperation improves the learning process. That is, participants will learn more under cooperation than under competition. We also hypothesize that (2) overall performance is greater under cooperation, than under competition. Since it is expected that participants will learn from repeated experience at the PM task (Parush, Davidovitch, and Shtub, 2006; Davidovitch, Parush, and Shtub, 2007), we anticipate (3) an improvement trend in both individual and pair performance.

II. METHODOLOGY

We examine the hypotheses posited by conducting an experiment using multiple participants performing simulated project management of a predefined task integrated with the use of project management software. The software, Project Management Trainer (PMT), is software developed in the Technion designed as a teaching aid to facilitate the teaching of project management in a dynamic, stochastic, multi-project environment. Such instructional innovations have been shown to be effective in promoting learning in science and engineering (Springer, Stanne, and Donovan, 1999; Johnson, Johnson, and Stanne, 1986). It is based on the following principles:

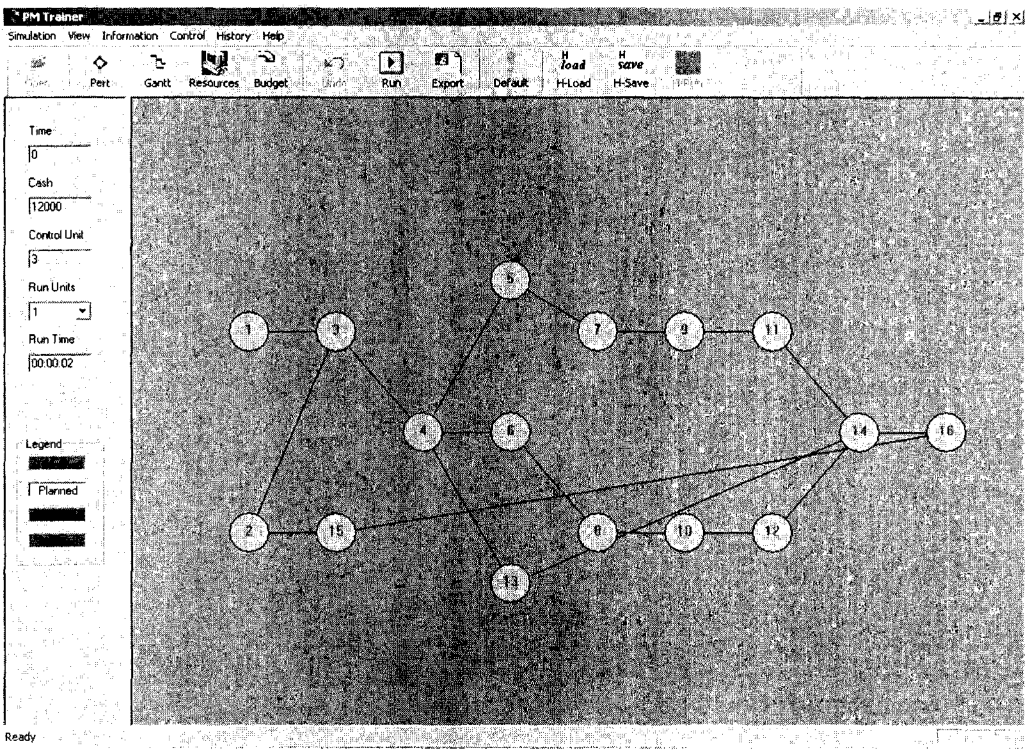
1. A simulation approach where the trainer simulates one or more projects. The simulation is controlled by a simple user interface and no knowledge of simulation or simulation languages is required.
2. A case study approach where the trainer is based on the simulation of case studies. Each case study is a project or a collection of projects performed by a specific organization under schedule, budget, and resource constraints, in a dynamic stochastic environment. The details of the case studies are built into the simulation and all the data required for analysis and decision-making is easily accessed by the user interface.
3. A dynamic approach, where the case studies built into the trainer are dynamic in the sense that the situation changes over time. A random effect is introduced to simulate the uncertainty in the environment, and decisions made by the user cause changes in the state of the system simulated.
4. A model-based approach, where a decision support system is built into the trainer. This system is based on project management concepts. The model base contains well-known models for scheduling, budgeting, and resource management monitoring and control.

To support decision-making further, a database is built into the trainer. Data on the current state of the simulated system is readily available to the users. Furthermore, it is possible to use the data as input to the models in the model base to support decision-making. This is done using an integrated approach, wherein several projects can be managed simultaneously. These projects share the same resources and a common cash flow. The PMT also includes a built-in learning history recording and inquiry mechanism as a new concept in training. Following this concept, the user has access to past states and decisions in the simulation, and to the consequences of these decisions. The effectiveness and efficiency of the history recording and inquiry mechanism were tested in a controlled experiment. The findings showed that there was a significantly better learning process with learning history recording and inquiry available to the users of a simulator (see Shtub, 2007).

The tasks that the participants conducted involved many aspects of the project management process. The specific steps taken by a subject were individual, and part of the learning process. However, they were comprised of a common set of elements including, evaluating the network model, task details, resources, cash flow, and project monitoring. The following is a brief description of each along with the corresponding PMT screen. The project activities and the precedence relationship between these activities are shown in a network diagram, as in Figure 1 (a). Detailed information on each task is accessible by clicking on the activity in the network.

Task details are accessible on the selected project activity including the modes in which the activity can be performed. The optimistic, most likely, and pessimistic duration of each mode, the cost associated with the mode, and the resources required to perform the activity in that mode, see Figure 1 (b).

Information regarding resources, requirements, and constraints is depicted on a resource histogram. The screen in Figure 1 (c) indicates information on the resource requirements for any



Time: 0

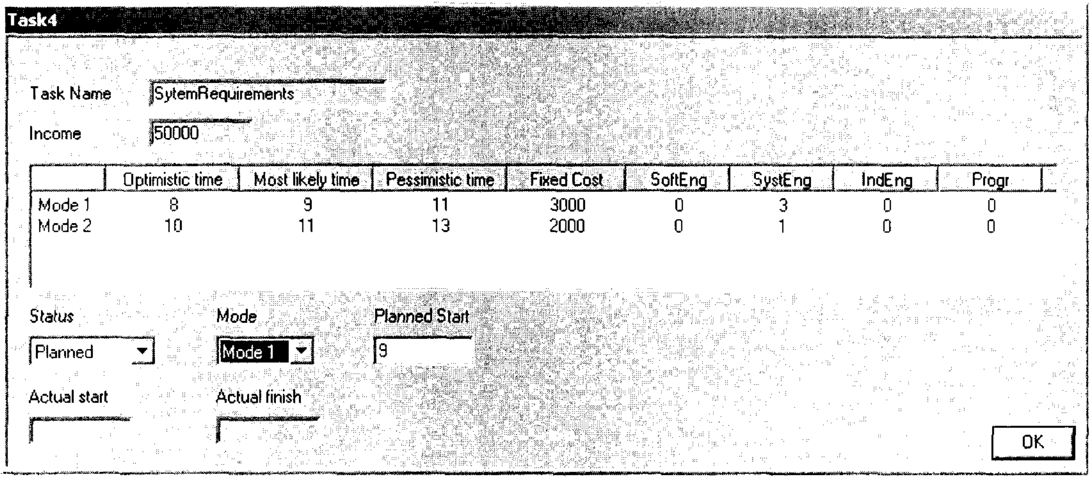
Cash: 12000

Control Unit: 3

Run Units: 1

Run Time: 00:00:02

Figure 1 (a). The network diagram.



Task Name: SytemRequirements

Income: 50000

	Optimistic time	Most likely time	Pessimistic time	Fixed Cost	SoftEng	SystEng	IndEng	Progr
Mode 1	8	9	11	3000	0	3	0	0
Mode 2	10	11	13	2000	0	1	0	0

Status: Planned

Mode: Mode 1

Planned Start: 9

Actual start:

Actual finish:

Figure 1 (b). Task details.

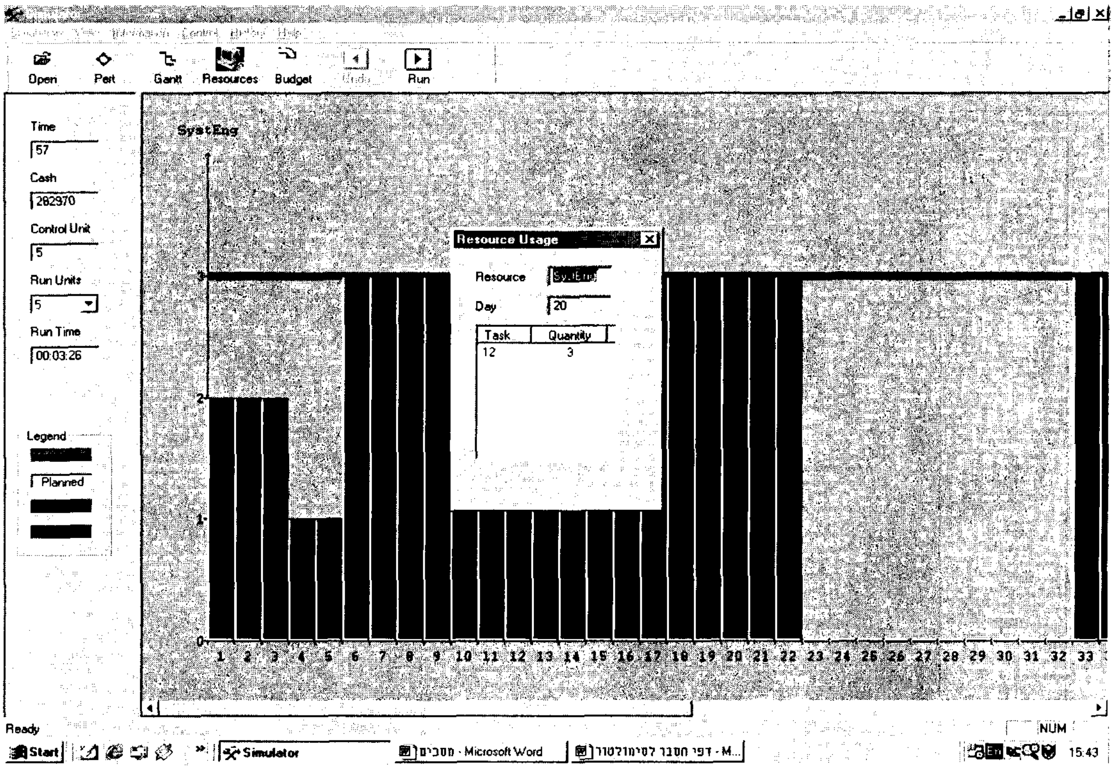
selected resource. By comparing requirements to availability, potential infeasibilities in task requirements can be identified.

A cash flow screen depicts information on both the positive and negative cash flows during the project as a function of time, as illustrated in Figure 1 (d).

The actual performance and project monitoring function can be obtained via another screen (in Figure 1 (e)) that depicts information on the actual progress of the project including the status of each activity, the mode in which it was performed, its planned versus actual duration, and its planned versus actual costs.

A. Sample

The participants in this study were 50 students enrolled in IE 425 (Introduction to Operation Research) at The Pennsylvania State University in Spring 2006. Students had junior or senior standing at the university, and majored in either industrial engineering or actuarial mathematics. All of the students did not receive any formal training in project management prior to the class enrollment. There was no detectable difference in capability anticipated or detected between the students in the different majors (*t*-test). Prior to the experiment, students had received three weeks of class



Time
57

Cash
282970

Control Unit
5

Run Units
5

Run Time
00:03:26

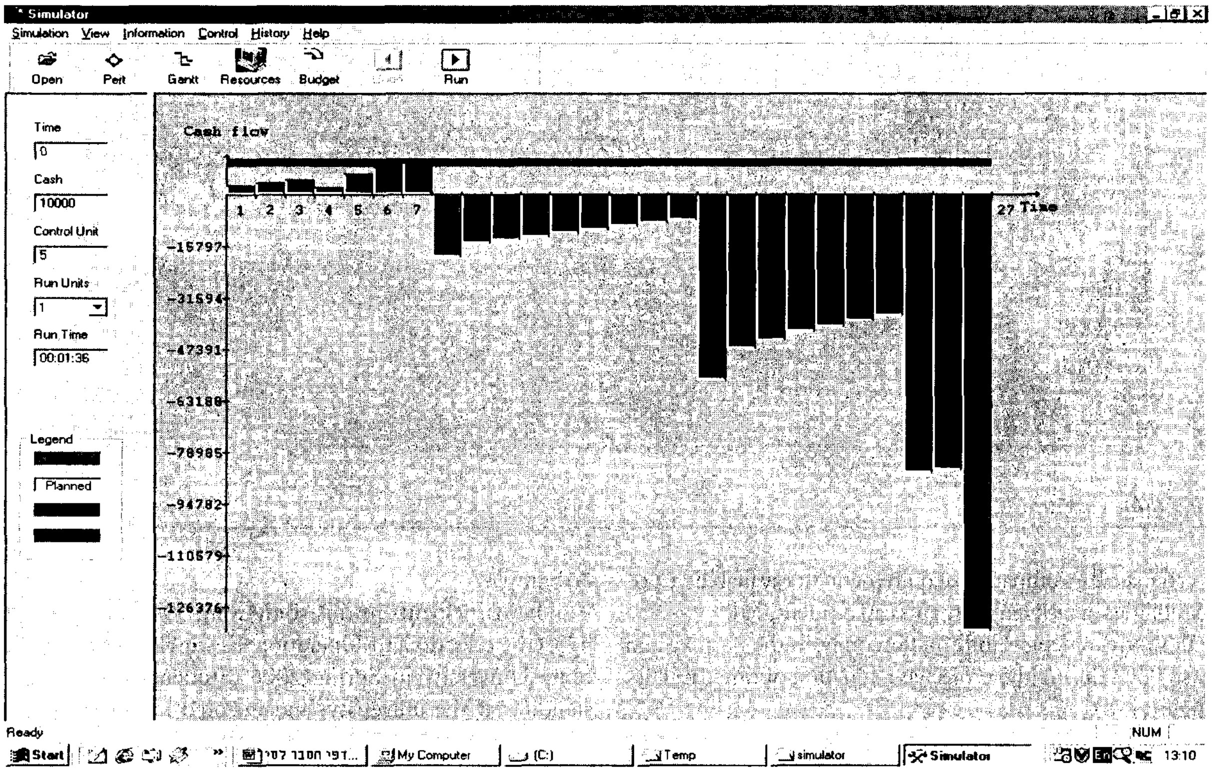
Resource Usage

Resource SystEng

Day 20

Task	Quantity
12	3

Figure 1 (c). Resource histogram.



Time
0

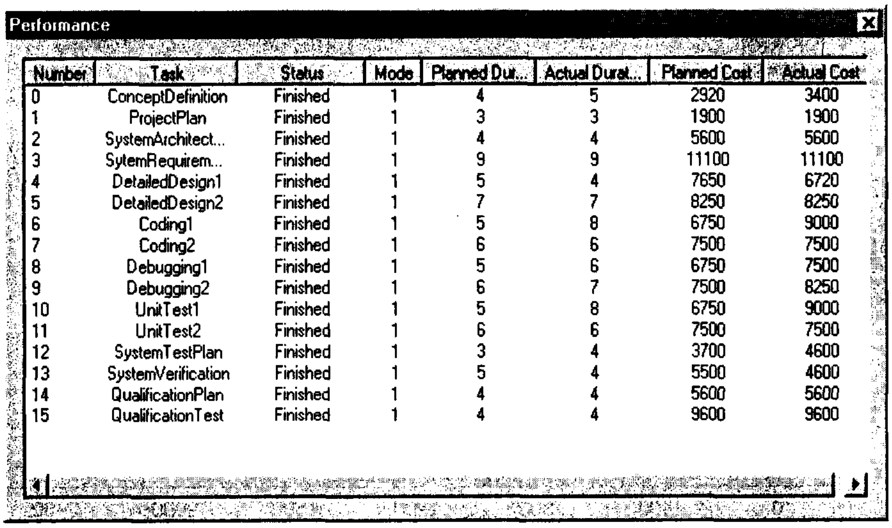
Cash
10000

Control Unit
5

Run Units
1

Run Time
00:01:36

Figure 1 (d). Cash flows.



Number	Task	Status	Mode	Planned Dur...	Actual Durat...	Planned Cost	Actual Cost
0	ConceptDefinition	Finished	1	4	5	2920	3400
1	ProjectPlan	Finished	1	3	3	1900	1900
2	SystemArchitect...	Finished	1	4	4	5600	5600
3	SytemRequirem...	Finished	1	9	9	11100	11100
4	DetailedDesign1	Finished	1	5	4	7650	6720
5	DetailedDesign2	Finished	1	7	7	8250	8250
6	Coding1	Finished	1	5	8	6750	9000
7	Coding2	Finished	1	6	6	7500	7500
8	Debugging1	Finished	1	5	6	6750	7500
9	Debugging2	Finished	1	6	7	7500	8250
10	UnitTest1	Finished	1	5	8	6750	9000
11	UnitTest2	Finished	1	6	6	7500	7500
12	SystemTestPlan	Finished	1	3	4	3700	4600
13	SystemVerification	Finished	1	5	4	5500	4600
14	QualificationPlan	Finished	1	4	4	5600	5600
15	QualificationTest	Finished	1	4	4	9600	9600

Figure 1 (e). Actual performance and project monitoring.

lecture in project management and one information session on the PMT software. We remark that, while proficiency at project management may take considerable time, a typical user can learn how to use the software within an hour. The experiment was assigned as an in-class project as part of the course requirement.

B. Procedures

The experiment was conducted in a computer classroom wherein students worked in randomly selected pairs from among the set of all 50 students, with each pair assigned to a workstation. Students from the two majors were randomly distributed throughout the pairs. Each pair was instructed to work by itself with the dynamic option to choose whether to cooperate with or compete with the other pair member. The pairs had the flexibility to change their strategy between trials. However, each student was instructed that their goal was to maximize both their individual profit and combined pair profit, to which their project grade was tied. It was left to the pairs to decide whether to compete or cooperate in attempting to maximize their grades on both individual and team criteria. The room capacity dictated that the experiment be separated into two 2-hour sessions during the same day. Conditions and instructions were identical for the two sessions.

The pairs were instructed to solve a 2-project, deterministic scenario in the PMT. Each member of the pair was responsible for planning and control of one of the two identical projects in the scenario. Each project consisted of seven events and seven tasks. Each task can be executed by two modes (a mode is defined by the combination of resources assigned to the task and the resulting duration and cost of the task). Each project had an associated due date. Completion of the project before the due date resulted in a bonus while a delay resulted in a penalty. There was a limit placed on the combined available resources and an associated idling cost charged for the idle time of unused resources. The goal of each participant was to choose the best mode for each task in order to minimize the total cost of the project, and thus to maximize the cash earnings of the project that the individual was in charge of. In addition, the goal of each pair was to maximize the total cash earning for the two projects combined. With respect to competition and cooperation, the rewards are these respective cash earnings. For the participants, the rewards are translated into a grade for this activity. Specifically, 50 percent of their grades would be determined by their team (pair) performance relative to other pairs, as quantified by their project's income. The other 50 percent of their grades would be determined by their individual performance relative to other individuals in the entire class, as quantified by their individual income. The subject pairs were asked to repeat the simulation for at least five runs. Each team was free to choose their strategy for each run to maximize its members' overall grades. For a team to choose cooperation or competition for each run, it would be based on whether the team's focus was on maximizing the team's performance or individual performances. The participants recorded the actual cost and final cash of the individual projects after each run on a data sheet. The final total cash values were recorded automatically by the software. We note that the measure in this study relates to the quality of the performance rather than the speed of performance. Thus, while many studies of learning behavior quantify reductions in the time to perform a standard task, we note that we employ the alternate perspective wherein we quantify the quality of the task performed. Beersma et al. (2003) provide a useful comparison of quality and speed under competition and cooperation.

C. Analysis

Since it is expected that participants will learn from repeated experience at the PM task (Parush, Davidovitch, and Shtub, 2006; Davidovitch, Parush, and Shtub, 2007), we anticipate an improvement trend in both individual and pair performance. We measured individual and pair performance using individual and pair earnings from the PMT, respectively. However, because the experiment involves relatively few repetitions (i.e., five), we separate the runs into two groups as a variance reduction technique. Uzumeri and Nembhard (1998) illustrate the need for such an approach given the relatively high variance between subjects and runs. Thus, the first three runs are grouped as stage-1, and the remaining two runs are grouped as stage-2. The variance between runs in stage-2 was great enough to obscure any learning curve effects within stage-2.

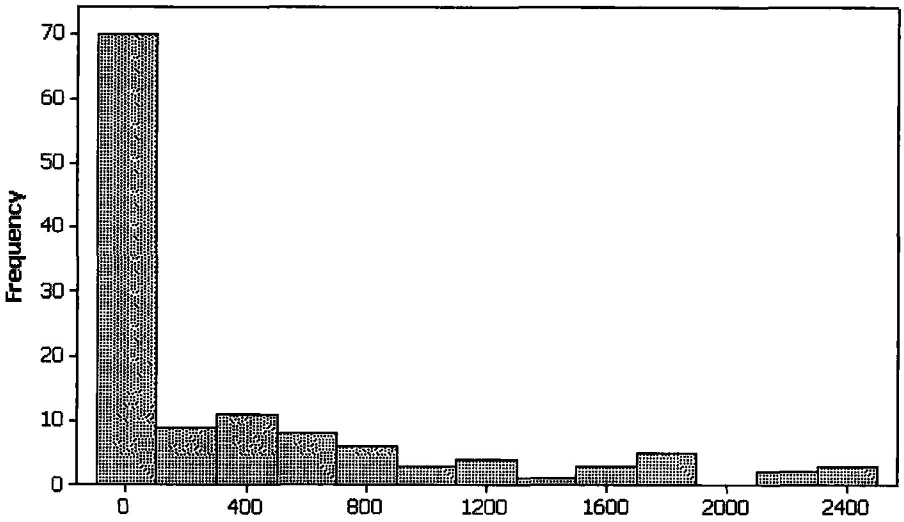


Figure 2. Performance differences within pairs.

The data from the experiment are examined in two ways; first based on individual performance, and second based on the performance within pairs. The latter examination may allow us to observe additional detail within the pair to help address questions related to strategy and learning. These will be modeled separately using a general linear model with the level of experience, learning strategy, and pairs as independent variables. We employ a standard one-way ANOVA for comparing among the strategies, and a repeated-measures ANOVA when comparing between the stages and in examining the interactions involving stages.

Since the two individual projects are identical and the available resources are unlimited, we note that when pairs cooperate, the members tend to make similar choices and hence the differences in project earnings within a pair are relatively small. On the other hand, when the pair competes, the two members make different choices in work modes and differences in project earnings between members are larger. Thus, the differences in individual project earnings within a pair are used as the surrogate measure of the cooperativeness among them. We note the possibility of coincidental similar performances between pair members. However, we remark that this is not likely to continue over repeated runs if they are truly competing and acting independently. Further, the defined strategies described tend to minimize the effects of any coincidences. Figure 2 illustrates the within-pair earning differences among all 125 runs (5 runs each for 25 pairs).

We define three strategy types for pairs based on the observed differences in individual performance.

1. We define a pair as having a *cooperative strategy* if at least 4 out of 5 runs are cooperative. That is, if the pair-wise performance is near zero in a supermajority of the runs. There were ten pairs that cooperated.
2. We define a pair as adopting a *mixed strategy* if between 2 or 3 out of 5 runs are cooperative. Nine pairs adopted a mixed strategy.
3. We define a pair as adopting a competitive strategy if at least 4 out of 5 runs are competitive. There were six pairs that competed.

Individual Performance	Stage 1 (Runs 1–3) ($n = 150$)	Stage 2 (Runs 4–5) ($n = 100$)
Mean	9,565	10,022
Standard deviation	993	754

Table 1. Summary of individual performance stage means (Repeated Measures ANOVA, Wilks' Lambda, $p < 0.001$).

IV. RESULTS

A. Individual Performance

We first examine how individual performance is affected by the strategy and the stage separately. There were 125 simulation runs collected from the pairs of students, and correspondingly, 250 data points for individual project earnings. Table 1 summarizes the means and standard deviations for the two stages using repeated-measures ANOVA. The results indicate an overall significant increase in individual performance from stage-1 to stage-2, which can be seen in Figure 3. Table 2 summarizes the means and standard deviations among the three strategies, which are illustrated in Figure 4. The one-way ANOVA on the strategy factor indicates a significant effect of the strategy chosen on the performance of the participants.

That is, both the stage and the strategy are significant factors influencing individual performance. Specifically, individual performance indicates that learning was generally taking place as subjects gained additional experience in later runs. Also, as seen in Figure 4, the cooperative strategy yielded a significantly higher individual performance, than either the mixed strategy or the competitive strategy. The mean performance for the mixed strategy was not significantly higher than that for the competitive strategy overall.

Figure 5 illustrates the significant interaction (within-subjects contrast F-test, $p = 0.043$) between stage and strategy for individual performance. One can note that learning is taking

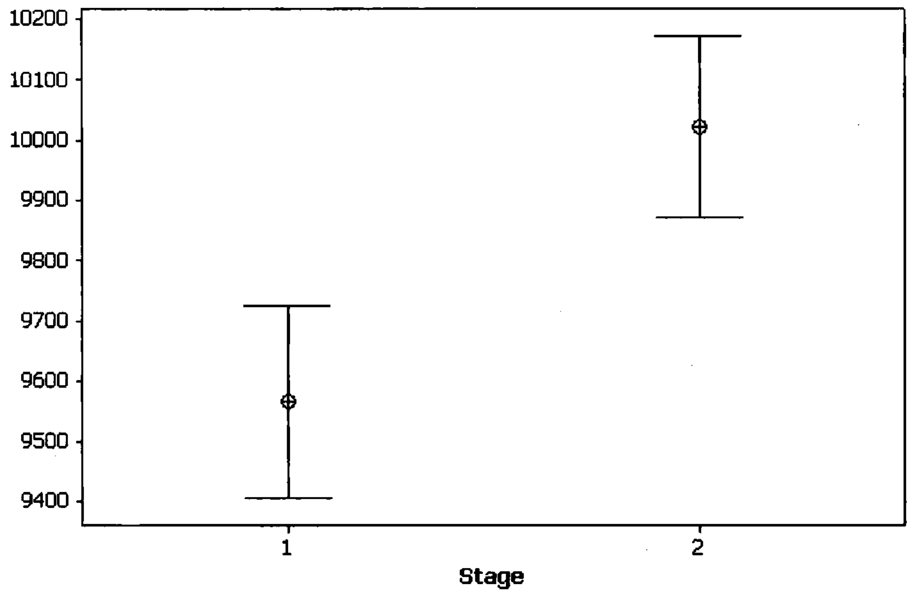


Figure 3. Individual performance versus stage (95 percent CI shown).

Individual Performance	Cooperative ($n = 100$)	Strategy Mixed ($n = 90$)	Competitive ($n = 60$)
Mean	10,090	9,690	9,265
Standard deviation	774	806	1,110

Table 2. ANOVA Results: Individual performance and strategy (ANOVA, F-test, $p < 0.001$).

place for the cooperating pairs and the competing pairs, with cooperation outperforming the competitive strategy. However, the mixed strategy performs similarly to the cooperative strategy in the early stage and like the competitive strategy in the later stage. Overall the mixed strategy exhibits negligible changes with additional practice.

B. Performance within a Pair

We also examine the performance within the pairs, with the goal of the examining the effects of stage and strategy by separating the higher performing pair member and the lower performing member's performance. Two dependent variables are used, *high* is the higher performance of the two individual earnings for each run, and *low* is the lower of the two. The results are summarized in Tables 3 and 4, and illustrated in Figures 6–8. Figure 6 illustrates that both the high and the low pair members showed significant learning from stage 1 to stage 2. By definition, high outperformed low in both stages. Figure 7 indicates some differences between high and low when it comes to strategy. For high, the differences between strategies are not significant. However, cooperation was significantly better than either the mixed or competitive strategies for the low performer (see Table 4 for p-values). Figure 8 illustrates the interactions between Stage and Strategy for the high and low pair members separately. Under cooperation, both the high and low performers showed significant improvement from stage 1 to stage 2, indicating in this case that both are learning. Under the mixed strategy, neither shows a significant change between stages. However, under competition, the high performer shows significant learning, while the low performer does not show a significant improvement.

V. DISCUSSION AND CONCLUSIONS

In this study, we hypothesized that (1) participants would learn more under cooperation than under competition. This hypothesis was partially supported. The results indicated that competition overall showed marginally greater improvement (learning), although the cooperation strategy significantly dominated that of competition. Further, we noted that the cooperative strategy was actually only significantly better than the other strategies for the low performer of the pair. The clear indication here is that the low performer has more to gain through cooperation, while the high performer does nearly as well on average regardless of the strategy. We also hypothesized that (2) overall performance is greater under cooperation, than under competition. It was supported by the results presented in Table 2 and Figure 4. Lastly, we hypothesized that (3) participants will learn from repeated experience. Evidence to support this hypothesis was presented in Table 1 and Figure 3. Overall, the results in this study indicate that cooperation is a favorable strategy in learning PMT. We notice that, with 50 participants, our sample size was relatively small. However, the sample size was similar to a typical class size. Nonetheless, results in the study were significant, which indicates that similar results may be observed in practice.

Comparing this study to the psychological classroom study (Sherman, 1986), the ages of the participants were similar. However, the findings of the two studies on the surface are not in complete agreement. While Sherman's study showed no significant differences in cooperative and competitive learning, cooperation is significantly more favorable than competition in simulation based

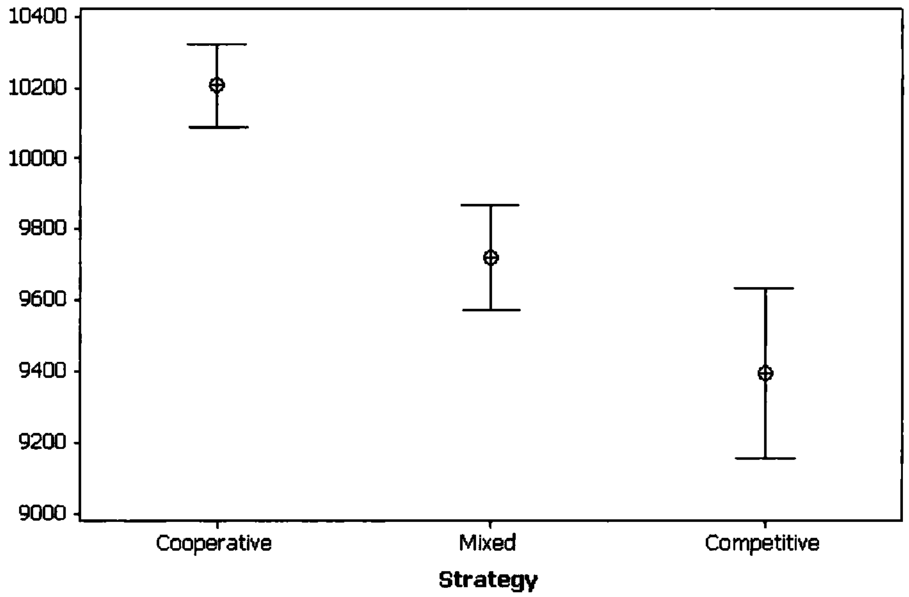


Figure 4. Individual performance versus strategy (95 percent CI shown).

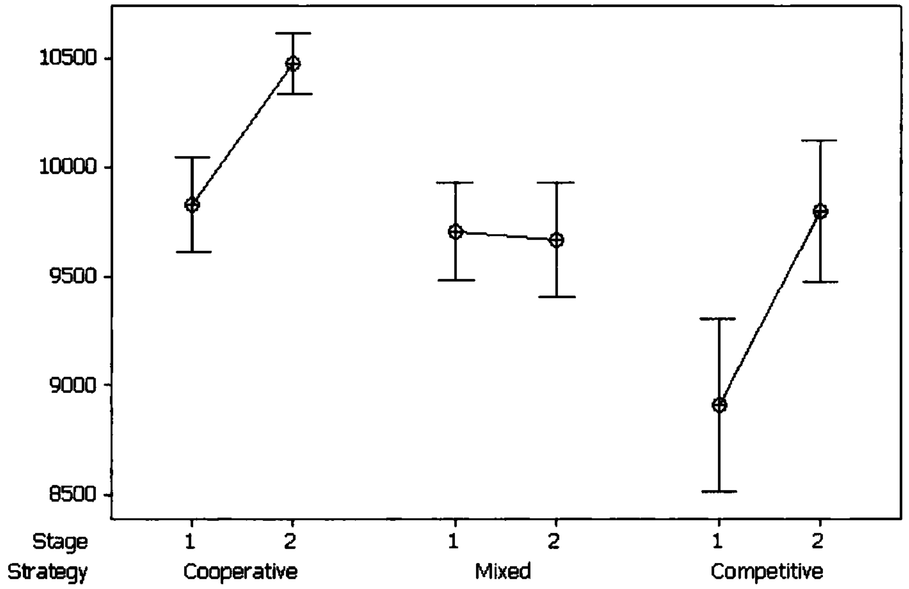


Figure 5: Interaction plot between stage and strategy (95 percent CI shown).

training. The cause of this difference may be due to the different problem type as well as the difference between the teaching methods. Qin, Johnson, and Johnson (1995), which investigated 46 individual studies and 63 findings, showed that while most findings support cooperation over individual competition learning, there were still several findings that came to other conclusions. Thus, the results in this study and in Sherman's may not conflict. In addition, the nature of PMT problems fall into the "ill-defined" problem category of Qin et al. (1995), which is one of the categories that cooperative learning more significantly outperformed competitive learning. In the meta-analysis conducted by Johnson et al. (1981), cooperative learning goal structures, both with and without intergroup competition, are more effective than individual competition.

Pair member	**High ($p < 0.001$)**		**Low ($p = 0.005$)**	
Stage	1	2	1	2
	($n = 75$)	($n = 50$)	($n = 75$)	($n = 50$)
Mean	9,756	10,225	9,374	9,819
Standard deviation	876	611	1,070	832

Table 3. Summary of within pair performance and stage (with repeated measures ANOVA, Wilks' Lambda).

Pair member	**High**			**Low**		
Strategy	Cooperative ($n = 50$)	Mixed ($n = 45$)	Competitive ($n = 30$)	Cooperative ($n = 50$)	Mixed ($n = 45$)	Competitive ($n = 30$)
Mean	10,129	9,930	9,655	10,050	9,450	8,875
Standard deviation	725	712	1,006	826	829	1,087

Pair member	**High**	**Low**
Cooperative vs. Mixed	$p = 0.182$	$p = 0.001$
Competitive vs. Mixed	$p = 0.169$	$p = 0.001$
Cooperative vs. Competitive	$p = 0.017$	$p < 0.001$

Contrast statistics between strategies

Table 4. Summary of within pair performance and strategy (with ANOVA, F-test).

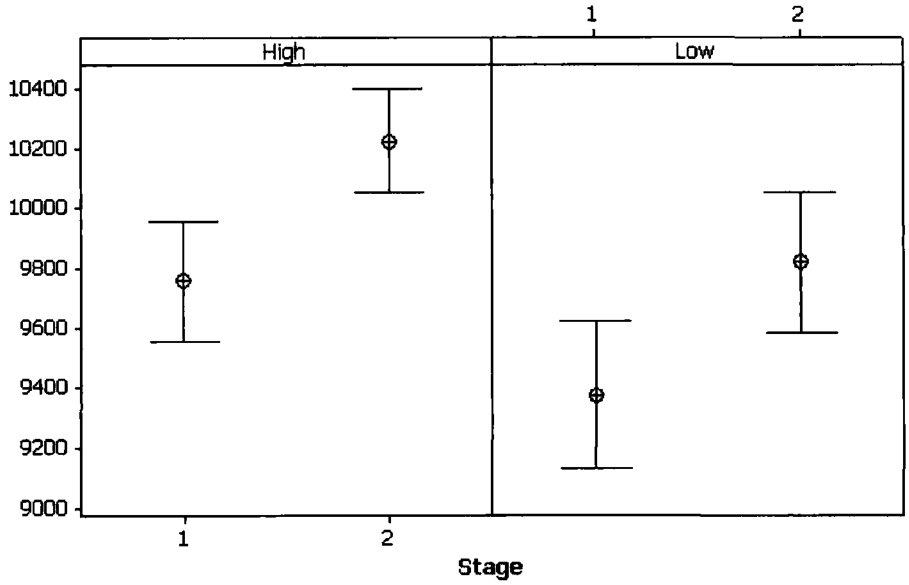


Figure 6. High and low pair members versus stage (95 percent CI shown).

These previous results support the conclusion that cooperation is preferred for PMT training. As a result, the next generation of PMT will be a group-training tool in which several students manage multiple projects simultaneously over the Web. The mixed strategy interestingly, showed no learning between stages. When inspecting the strategy switching patterns of the mixed strategy teams, we did not observe a common pattern. Some teams used one strategy for two consecutive runs and then switched between the two strategies for the remainder of the runs. Some teams started with one strategy, then used another strategy for two consecutive runs and then switched back to their original strategy. Out of the nine mixed strategy teams, five teams switched their strategies three times, three teams switched two times and one team switched one time. This may be an indication that these teams had not yet found their preferred strategy within five runs. We know that students' performance improved as they repeated the task. We speculate that indecision regarding strategy does not yield good results in learning because students have to switch their modes of learning (either cooperative or competitive) from time to time, and hence spending much effort in adapting to the learning modes rather than learning to improve the required task.

The use of simulation tools in project management teaching has significant potential. The participating students gave positive feedback and commented that simulation gave a more realistic and motivating experience compared with traditional lectures. In this context, a pedagogical system designed for a cooperative learning strategy may be beneficial to the students. We further note that from a learning perspective, a competitive strategy also yields improved performance, but the students may not get the full benefit of a teammate's ideas or understanding. Overall, it is perhaps most helpful for the lower performing students to be paired with a higher performing student in a cooperative setting. This bears

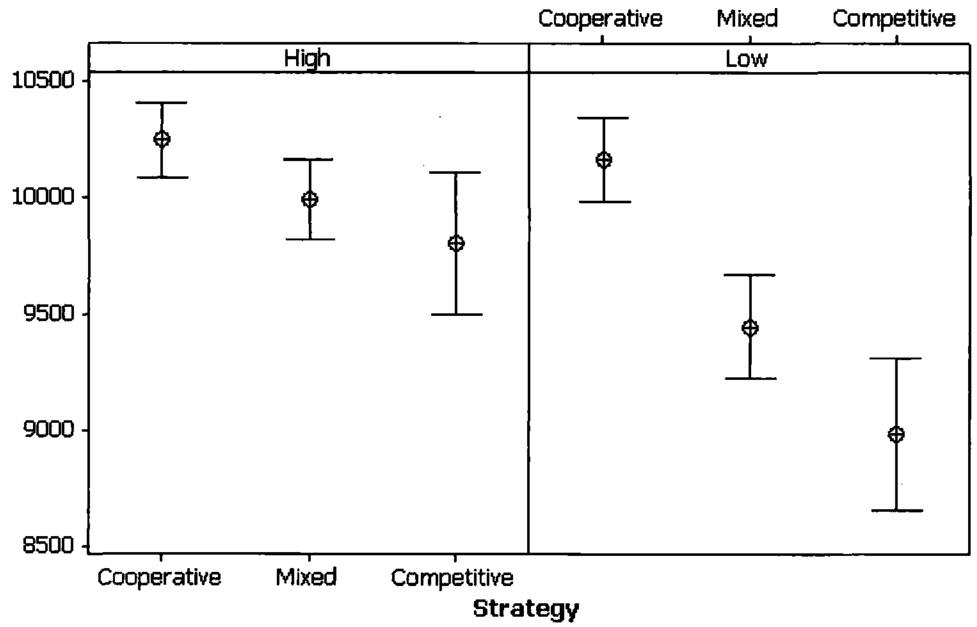


Figure 7. High and low pair members versus strategy (95 percent CI shown).

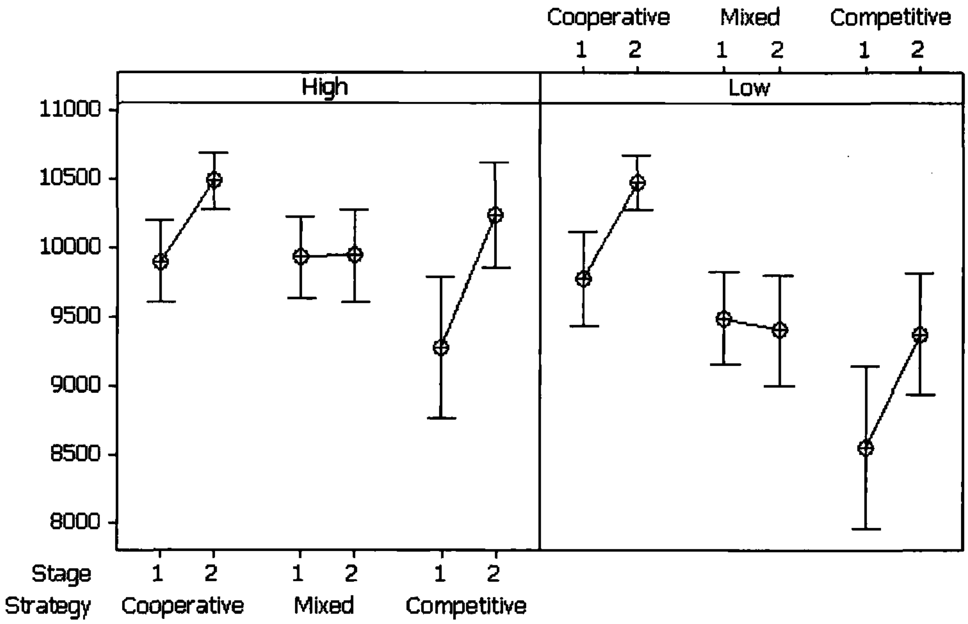


Figure 8. Interaction plot of stage and strategy for high and low pair members (95 percent CI shown).

some similarity to a result described by Beersma et al. (2003) in which the impact on the performance quality of the poorer performer is greater than the impact on the better performer in a cooperative setting. We note that learning in these cooperative contexts is a close representation of situations in projects that involve working in teams.

While this study concentrated on the benefits of learning project management using cooperative learning and competitive learning in the PMT environment, we believe the results are helpful to the field of engineering education in general. First, project management is one of the major disciplines of engineering. The ability to manage and organize resources is essential to projects in all fields of engineering. Second, simulation-based training is becoming a trend in engineering education, especially for tasks with high complexity. This paper has given some ideas of cooperative learning and competitive learning for training project management, as well as tasks with high complexity, in simulation-based environment.

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