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Evaluating a Project Management Simulation Training Exercise

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Abstract

This research is an evaluation of a single-player, project management simulation training exercise. Our objective is to gain understanding about the extent to which it contributes to participants' project management knowledge and skills. Results from pre- and post-simulation exercise questionnaires indicate that overall the simulation exercise significantly improves a participant's conceptual knowledge about project management. It also indicates that participants with less experience achieve more knowledge improvement than those with more experience. Results further indicate that the actual performance of the exercise, which represents the educational value of the exercise, is primarily dependent on the post-project management knowledge of the participant established throughout the exercise, prior knowledge brought to the exercise, and the experience of the participant. We believe that these results indicate that the simulation training exercise is a valuable training tool, which both engineering and project managers can use.

Keywords

exercise, gaming, post-exercise questionnaire, pre-exercise questionnaire, project management, project management knowledge, project management training, simulation

The project management body of knowledge (PMBOK®) developed by the Project Management Institute (2008) defines project management (PM) as the "application of knowledge, skills, tools, and techniques to project activities to meet the project requirements." The PMBOK® specifically presents all project activities based on

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two criteria: five project management process groups (PMPGs)—initiating, planning, executing, monitoring and control, and closing—and nine project management knowledge areas (PMKAs)—integration management, scope management, time management, cost management, quality management, human resource (HR) management, communication management, risk management, and procurement management.

The initiating process group includes all activities to define a new project or a phase from an existing project. The planning process group consists of all activities to establish the total scope of the effort required to complete a project successfully. Hence, it defines the objectives of a project and develops all actions to accomplish those project objectives. The executing process group includes activities performed to complete the work defined in the project management plan obtained from the planning process group. The monitoring and control process group consists of two subgroups—monitoring and control. Monitoring refers to those activities required to track and review the progress and performance of a project, and control includes activities required to regulate the progress and changes to fill any gap between current progress and an approved plan. The closing process group consists of activities required to finalize the project officially. Along with those five PMPGs, project management activities are also classified into nine PMKAs. The definition of each PMKA is well conveyed by its name, except the integration management knowledge area, which includes activities required to identify, define, combine, unify, and coordinate diverse project management activities within PMGs. We encourage readers to refer to the PMBOK® by the Project Management Institute (2008) for detailed explanations on definitions of PMKA. Based on these two criteria—PMPG and PMKA, each project management activity defined in PMBOK® belongs to at least one PMPG and one PMKA. For example, an activity "develop project charter" belongs to the initiating process group and the integration management area, and the activity "develop project management plan" belongs to the planning process group and integration management area. According to the aforementioned definition of project management, to be a successful project manager, an individual needs understanding of theories (e.g., knowledge, skills, tools, and techniques) about project activities and also the application capability of those theories to complex real life environments; this capability being built through practice.

As described in Riis, Smeds, Johansen, and Mukkelsen (1996), individuals learn through a process of conceptualization and experimentation. They explained that conceptualization is a process to invent or contrive ideas or theories, and individuals develop relevant knowledge based on those. This is closely linked to the traditional lecture-based learning using textbooks and notes in the classroom. Experimentation is a process of applying and testing conceptual knowledge through practice—applying the knowledge to specific situations. This process is linked to a variety of teaching methodologies such as using simulation and case studies in the classroom environment.

As a tool for learning by experimentation, simulation has a long history. One of the most popular and recognized simulation games as a training tool is the BEER GAME, developed by MIT's Sloan School of Management in the early 1960s (Sterman, 1989).

In this game, participants play roles as decision makers in a simple serial supply chain to distribute cans of beer to customers by manipulating order and replenishment quantities at each of four decision points according to the participants' roles in the supply chain (Goodwin & Franklin, 1994). The detailed functional and mathematical descriptions of its roles and their functional effects on the total supply chain in terms of total cost are well analyzed and described by Jeong and Hong (2011). The success of this BEER GAME significantly motivated further development of other simulation games for training and education. The use of simulation games as a training tool has been popular in business and engineering areas because of the following advantages:

- A simulation game can provide more realistic and dynamic environments that are usually not available in the traditional lecture-based education.
- Participants can see the consequences of their decisions and can also learn lessons from them without any risk of failure.
- Simulation games can trigger participants' motivation for learning.
- Simulation games can also be used to evaluate and improve teamwork related to the decisions.

The effectiveness and usefulness of simulation and games have been discussed extensively in literature for decades, recently reviewed by Chin, Dukes, and Gamson (2009).

Although simulation games have been popular tools for education because of their advantages, and many researchers have investigated and demonstrated their effectiveness as a training tool, only a limited number of previous studies have focused on project management simulation games (PMSGs). Even among existing studies, many tend to emphasize PMSG software itself by introducing tutorial and performance measurement mechanisms (Levi, 2011; Vanhoucke, Vereecke, & Gemmel, 2005), or verified results generated by a tool (Pfahl, Klemm, & Ruhe, 2001). Very few authors have used PMSG to show its effectiveness as a training tool (Davidovitch, Parush, & Shtub, 2006; McCreery, 2003; Zwikael & Gonen, 2007). Therefore, we believe that investigating the influence of PMSG on project management learning will help to round out this knowledge base.

In this article, we study the use of simulation in a project management training exercise, and evaluate its influence as a training tool, based on a training exercise conducted in a nontraditional classroom setting in which the majority of students are working professionals with 1 to 5 years of experience in engineering and technical areas. Therefore, the results and insights obtained from this research will prove to be useful to both researchers and industry practitioners who wish to use and develop project management simulation as a training tool.

Literature Review

Research is plentiful regarding the effectiveness of simulation games as a learning tool in both business and engineering areas. We encourage readers to refer to Forssen and

Haho (2001) and Deshpande and Huang (2009) to obtain comprehensive knowledge on diverse simulation games for training. Forssen and Haho provided a review of 88 business process improvement simulation games, and claimed that simulation games could improve both individual and organizational learning, whereas Deshpande and Huang provided an overall review on specific simulation games used in the education of seven different engineering disciplines (e.g., computer engineering and industrial engineering).

Although simulation games have been a popular tool for training and education, literature shows that little research has been conducted in assessing the value of a project management simulation game as a training tool. Among those, Cano and Sáenz (2003) presented the concept of a PM simulation lab consisting of instructors, participants, observers, and simulators. They used the simulation game PROSIGA (PROject SImulation GAme) for PM training, and analyzed feedbacks from participants. They reported that individual factors (e.g., game complexity, previous experience, age) explained 45% of learning from experience, measured by Likert-type questionnaires after the simulation game. McCreery (2003) assessed the value of PM simulation as a training tool using pre- and post-simulation surveys. His statistical analysis showed that many training participants perceived that their project management knowledge level (PMKL) was improved after the simulation training exercise. He also analyzed the relationship between perceived PMKL improvement and actual team performance measured by a composite performance score with consideration of the project cost spent and project duration taken to complete the project per team. In his study, no significant evidence was found to support the view that actual team performance has an effect on the perceived educational value of the exercise measured by the PMKL improvement. He also showed that the quality of a team process was not a significant factor on the perceived PMKL improvement. Zwikael and Gonen (2007) used the simulation game called Project Execution Game (PEG) and evaluated its effect on participants' perceived PM knowledge using the pre- and post-simulation game surveys. Participants showed significant perceived PMKL improvement in areas such as integration, human resource, and risk management while they showed moderate PMKL improvement in the knowledge areas and process groups such as scope, time, procurement, planning, and monitoring and control. Unexpectedly, the PMKL improvement in cost management was not significant. They did not evaluate the quality and communication knowledge level improvement in their analysis. Davidovitch et al. (2006) used the Project Management Trainer (PMT) simulation software to evaluate two performance history track modes: the manual history mode where participants must manually record performance of the simulation progress and the automatic history mode where all histories are automatically recorded. They identified that participant's performance using the manual history mode was significantly better than that using the automatic history mode.

Compared with previous research, we use the following unique approaches in this study:

- The focus is on an individual rather than a team—that is, a single-player simulation game is used rather than a multiple-player simulation game. Many

previous authors assessed individuals' perceptions concerning the simulation training exercise based on team-based, multiple-player training exercise activities. However, it is sometimes difficult to assess the value of a PM simulation game accurately as a training tool at an individual level in a team-based environment. Harteveld and Bekebrede (2011) concluded in their research on single versus multi-player games that when an objective is to focus on transferring specific knowledge and skill sets, a single-player approach is more appropriate; this is why we adopt a single-player PM simulation game.
- PMBOK® is used to assess individuals' perceived PMKL in terms of five PMPGs and nine PMKAs.
- Finally, the main focus is on an individual's actual performance in a simulation training exercise, which may be interpreted as the educational value of the exercise. Therefore, investigating what factors affect an individual's actual performance would provide many insights to practitioners and researchers who want to use simulation games for training and research purposes, respectively.

We believe that these unique approaches extend existing research and will provide useful insights to researchers and practitioners who consider the simulation exercise to be a potential training tool.

Research Methodology and Setting

We used the following survey-based research methodology to evaluate project management simulation as a training and learning tool:

- develop relevant hypotheses to assess the simulation exercise and to evaluate the effects of relevant factors within the exercise
- administer a pre-exercise survey
- deploy a simulation exercise using a single-player simulation game
- administer a post-exercise survey
- evaluate and analyze hypotheses

We have collected the data for this study from the graduate project management classes offered at the University of Houston-Clear Lake (UHCL) for 2 years, starting from 2010. A total of 47 students from the Engineering Management program have participated in the surveys; 20 students in 2010 and 27 students in 2011. Most of those students were working professionals with 1 to 5 years of industry experience in engineering and technical areas, and were between the ages of 25 and 35.

The project management class is a 15-week long course covering the nine PMKAs and five PMPGs according to the PMBOK®. During the first 11 weeks, we have used diverse teaching methodologies such as lectures, case studies, written exams, essay writings, and individual and team assignments. Students began the simulation exercise using "SimProject" developed by Fissure (SimProject, 2011) at Week 12; they were required to complete their final team project management plan and the corresponding group presentation at Week 15. They completed the pre- and post-simulation exercise questionnaires at Weeks 11 and 13, respectively, so that we could evaluate the effects of the exercise on their PM learning and training. We allowed participants to repeat the simulation exercise multiple times. However, whenever they repeated the exercise, they had to restart all exercise processes.

Project Management Simulation Game

The single-player PM simulation game, SimProject, developed by Fissure (SimProject, 2011) is different from the SimProject game developed by Pinto and Parente (2003), which is a multiple-player game for team-based activities. As a single-player game, SimProject has the following advantages:

- It is very practical and easy to use while covering almost a full life cycle of project management—a participant begins the exercise by reading the project charter and other relevant project management documents, and the game ends when the participant completes the project.
- It is easily accessible—as the software is commercially available for training, any researcher or practitioner can download it from the developer's website.
- It has many convenient project progress monitoring functions such as an earned value management system (EVMS) and a Gantt chart tracking function to support the planning, execution, and monitoring and control. Therefore, participants can focus more on PM issues rather than technical issues to track the progress of the game.
- It provides diverse and realistic unexpected event scenarios during the execution phase. Therefore, a participant must manage those unexpected events real time as in many real life PM cases.

In the SimProject, a participant works as a project manager to manage a fictitious alliance prototype project (APP) to augment the sales and marketing of a company called "Uniworld" with an e-commerce equipped website. The fictitious APP consists of 7 tasks, with an approved budget of US$50K during 11 weeks. According to the success criteria, the website should not have more than seven known defects. Figure 1 is an explanation of how to participate in the simulation game—some previously discussed process groups are considered here as a phase. In the *initial learning phase*, a participant (a project manager) needs to read several project-related documents including a project charter, project descriptions, company regulations, and resource profiles to develop their knowledge of the project. In the *planning phase*, the participant performs all planning activities such as team member hiring based on task requirements and resource profiles (staffing), assigning each resource to a task (task assignment), and scheduling meetings for team members, trainings, and stakeholders during the entire planning time horizon (11 weeks). Multiple resources may be available for a task, and depending on the strategy, the project manager can choose specific team members among multiple resources available.

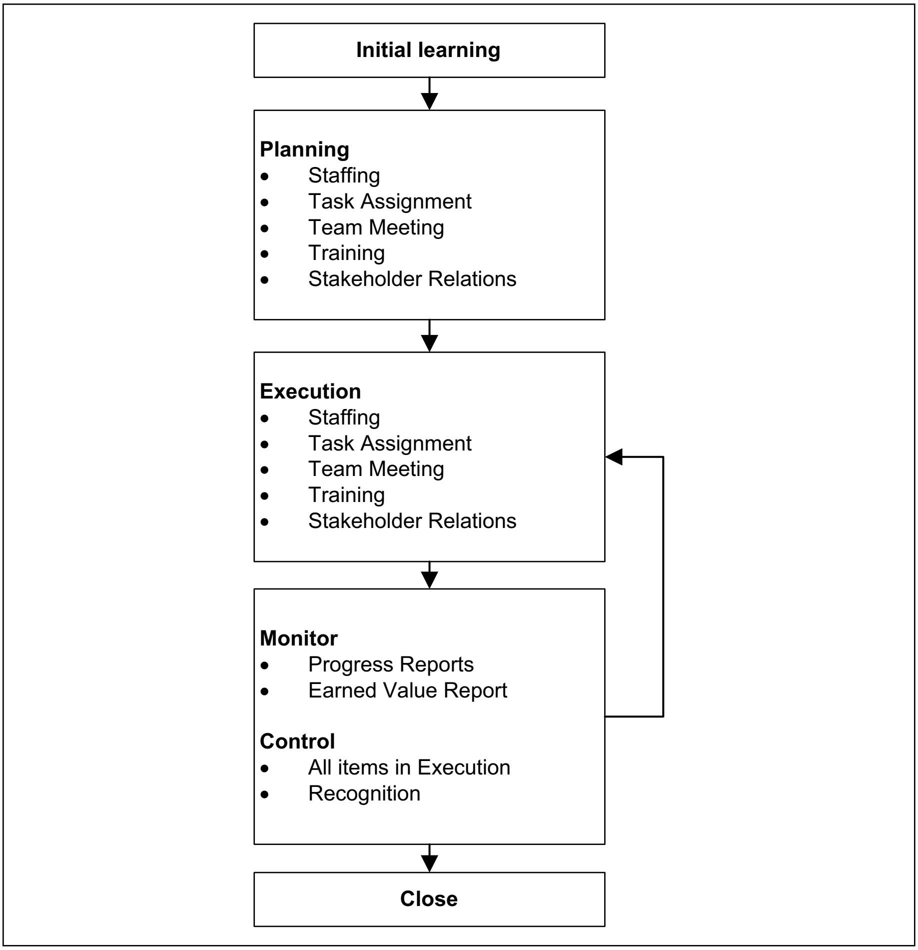
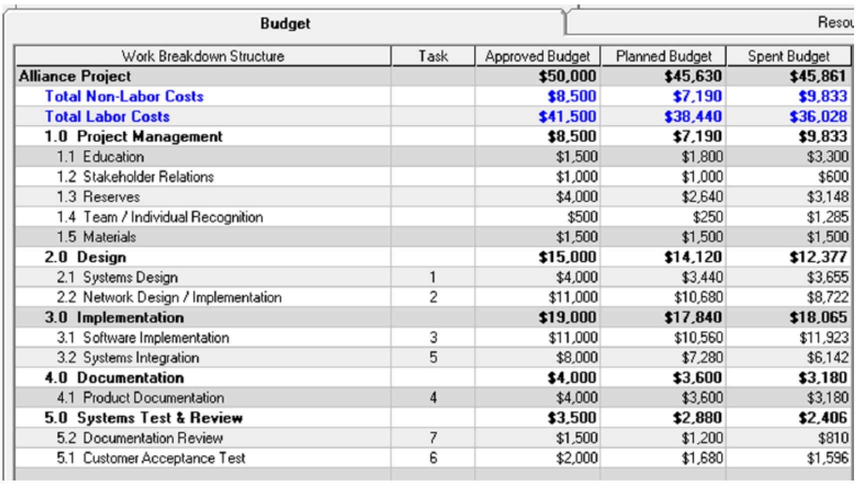


Figure 1. Simulation implementation cycle.

During the *planning phase*, whenever the project manager changes and updates the PM plan according to diverse strategies, the corresponding planned budget is automatically updated because of this change. Figure 2 shows all budget-related items for an entire work breakdown structure (WBS) for the APP project. “Approved Budget” in the third column shows the total available budget for each item in WBS. “Planned Budget” in the fourth column is updated based on the project manager’s strategy—US$45,630 in this case. One of the outputs of this planning phase is the cost baseline of the entire project against which we compared the actual progress of the project.

In the *execution phase* where the *monitoring and control* activities concurrently occur, the project manager needs to develop and execute each week’s execution plan



Work Breakdown Structure	Task	Approved Budget	Planned Budget	Spent Budget
Alliance Project		**$50,000**	**$45,630**	**$45,861**
Total Non-Labor Costs		**$8,500**	**$7,190**	**$9,833**
Total Labor Costs		**$41,500**	**$38,440**	**$36,028**
1.0 Project Management		**$8,500**	**$7,190**	**$9,833**
1.1 Education		$1,500	$1,800	$3,300
1.2 Stakeholder Relations		$1,000	$1,000	$600
1.3 Reserves		$4,000	$2,640	$3,148
1.4 Team / Individual Recognition		$500	$250	$1,285
1.5 Materials		$1,500	$1,500	$1,500
2.0 Design		**$15,000**	**$14,120**	**$12,377**
2.1 Systems Design	1	$4,000	$3,440	$3,655
2.2 Network Design / Implementation	2	$11,000	$10,680	$8,722
3.0 Implementation		**$19,000**	**$17,840**	**$18,065**
3.1 Software Implementation	3	$11,000	$10,560	$11,923
3.2 Systems Integration	5	$8,000	$7,280	$6,142
4.0 Documentation		**$4,000**	**$3,600**	**$3,180**
4.1 Product Documentation	4	$4,000	$3,600	$3,180
5.0 Systems Test & Review		**$3,500**	**$2,880**	**$2,406**
5.2 Documentation Review	7	$1,500	$1,200	$810
5.1 Customer Acceptance Test	6	$2,000	$1,680	$1,596

Figure 2. Budget window.

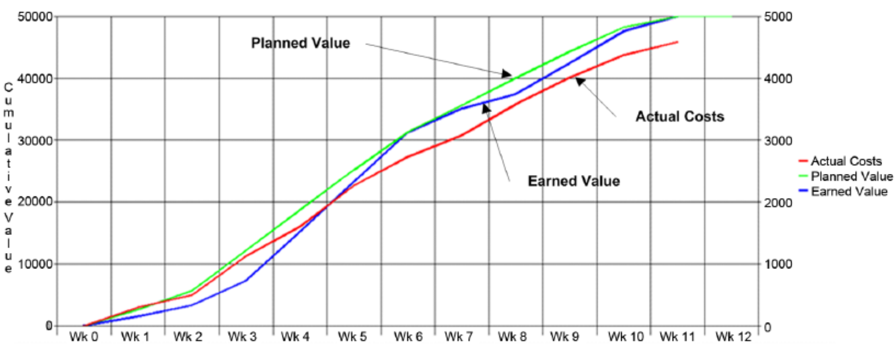


Figure 3. Earned values report.

separately. During this phase, the project manager can change the original plan by *monitoring* the progress of the actual project. For example, while the project manager is executing each week's execution plan, several unexpected events may occur, and the project manager needs to manage them interactively using diverse reports such as the progress report and the earned value report (see the earned value report in Figure 3). Some of these unexpected events include a scope change request by customers, absence of project members, personality conflicts between team members, and stakeholder meeting requests. These may create deviation from the original plan. The project manager should interactively *control* the project by taking appropriate corrective

Table 1. Pre-Exercise Questionnaire.

Prior SimProject questionnaires
Section 1: Your project management knowledge evaluation
Use the following scale to assess your knowledge level in the given questions:
(1 = *extremely low*; 6 = *extremely high*)
1. Assess your knowledge level in scope management.
2. Assess your knowledge level in time management.
3. Assess your knowledge level in cost management.
4. Assess your knowledge level in quality management.
5. Assess your knowledge level in human resource management.
6. Assess your knowledge level in risk management.
7. Assess your knowledge level in communication management.
8. Assess your knowledge level in procurement management.
9. Assess your knowledge level in integration management.
10. Assess your knowledge level in the project initiating process.
11. Assess your knowledge level in the project planning process.
12. Assess your knowledge level in the project executing process.
13. Assess your knowledge level in the project monitoring and control process.
14. Assess your knowledge level in the project closing process.
Section 2: Experience
Use the following scale:
1 = *low* (1-3 years), 2 = *medium* (3-5 years), 3 = *high* (more than 5 years).
15. How much project management experience do you have?

and preventive actions (e.g., using employee recognition and awarding, hiring and firing, and finding a substitute) using their PM knowledge and know-how to fill the gap. Eventually, a task will have one of the three final states at each execution: "delayed," "completed earlier," or "finished on time." Whenever executed, the simulation clock is advanced to the next week, and the project manager is ready to develop and execute the next week's execution plan again as indicated by the upward arrow in Figure 1. This cycle repeats until all job contents are completed. During the *close phase*, the project ends. Actual performance of the game is recorded as the total budget spent and total project duration taken, and the results vary depending on strategies used and the project manager's management skills (expertise). During and after the game, the software tracks several performance metrics. For example, see the actual project cost spent in the "Spent Budget" column of Figure 2—It is US$45,861 in this case. Figure 3 is a graphical display of the earned value report from a sample run. It shows the planned value, earned value, and actual costs spent over time.

Research Instrument

We assessed the simulation exercise through pre- and post-exercise questionnaires at Weeks 11 and 13, respectively. The pre-exercise questionnaire consisted of 15 questions listed in Table 1. We use questions in Section 1 to assess the participant's project management knowledge level (PMKL) based on PMBOK®—nine PMKAs (Questions

Table 2. Additional Questions in the Post-Exercise Questionnaire.

Section 3. Exercise evaluation
Assess your experience with the simulation exercise using the following scale:
(1 = *extremely low*; 5 = *extremely high*)
1. Do you think the game was useful for this course?
2. Was the simulation interesting and challenging?
3. How would you grade the game's level of complexity?
4. Did the game contribute to your project management knowledge?
5. Did the game provide you with overall concepts of project management?
Section 4. Your effort for this simulation exercise
6. How many times have you tried the SimProject until you completed all works?
7. Approximately how many hours have you spent with SimProject?
Section 5. Your game performance
8. How many simulation weeks did it take for you to complete the APP project (e.g., 12 weeks)?
9. What was your actual cost spent?

Note. APP = alliance prototype project.

1-9) and five PMPGs (Questions 10-14). We use the questions in Section 2 to classify each participant's project management experience level (PMEL) into three levels. We use a 6-point scale to reduce the possibility of the neutral answers that is often caused by the 5-point or 7-point scale. The rationale for this is that our survey participants are familiar with the conceptual PM knowledge through multiple-week training and education.

In the post-exercise questionnaire, we added several additional questions to the original questions, as seen in Table 2. These additional questions are to evaluate participant's perception on the exercise (Section 3), their effort spent (Section 4), and their actual performance in the simulation exercise (Section 5).

Research Hypotheses

We expected that the simulation exercise would help participants improve their perceived PMKL. The interactive learning through experimentation from planning to closing during the exercise will contribute positively to participants' perceptional PM knowledge improvement. This leads to the expectation that PMKL assessed in the post-exercise survey is higher than that assessed in the pre-exercise survey. Hence, the associated hypothesis is as follows:

> **Hypothesis 1 (H1):** Participants' perceived knowledge on project management will be improved after completing the exercise compared with the perceived knowledge level before the exercise.

We investigated the effect of PMEL on participants' learning represented by the PMKL because the experienced project manager has been considered one of the most important critical success factors in many projects (Munns & Bjeirmi, 1996; Verburg, Bosch-Sijtsema, & Vartiainen, 2013; White & Fortune, 2002). For this, we classified the participants into three levels (low, medium, and high) according to their PMEL, which is evaluated by Question 15 in Table 1. The PM experience includes any job experience as a program manager, project manager, project team coordinator, and project team member, among others. We expected that participants with more PM experience would start and finish the exercise with higher level PM knowledge compared with those with less PM experience. Hence, the associated hypotheses were as follows:

> **Hypothesis 2 (H2):** Prior to performing the exercise, the level of project management knowledge is higher for participants with more project management experience than for those with less project management experience.
> **Hypothesis 3 (H3):** After performing the exercise, the level of project management knowledge is higher for participants with more project management experience than for those with less project management experience.

Participants with less PMEL may be less familiar with the knowledge and techniques provided in the exercise. In addition, they can be considered relatively new learners from the perspective of this exercise compared to those with more PMEL. We believe that new learners are likely to be more attracted and motivated by new knowledge and techniques than other participants are and this increased motivation will provide a better chance to improve their PMKL (McCreery, 2003). Hence, while all participants are beneficiaries of this exercise, we expected that it is easier to improve new learners' PMKL than those with more PMEL. Therefore, we developed the following hypothesis:

> **Hypothesis 4 (H4):** Participants with less project management experience will show a higher rate of PM knowledge improvement than those with more project management experience after the exercise.

Following this, we investigated the effects of PMEL and the effort spent in the exercise, respectively, on actual performance of the training exercise, which is evaluated in terms of the project cost spent and project duration taken to complete the fictitious project. We considered both metrics in this exercise because these two metrics well represent the actual performance of a project as part of the triple constraint of project management defined by Project Management Institute (2008). We expected that those with more PM experience are more accustomed to managing the project activities in reality. As we intended this simulation training exercise to mimic real life practices, it is logical to expect that those with more PM experience were likely to have higher performance in the simulation exercise; this is represented in the hypothesis below (H5). Mayer, Dale, Fraccastoro, and Moss (2011) emphasized the importance of the financial decision in a business simulation game by showing that participants' deliberation or effort on a financial decision represented by financial metrics was positively related to participants' perceptional learning. Rompho (2011) also echoed Mayer et al.'s statement. However, none of those studies analyzed the relationship between participants' effort and actual performance. Hence, we needed to study it in this research. We attempted to capture the participants' effort spent in this exercise with two variables: the number of repetitions of the game and total actual time spent by a participant to complete the game, as listed in Section 4 of Table 2. We expected that those who spend more effort in this exercise are likely to have better performance than those who spend less effort (H6).

Hypothesis 5 (H5): Participants with more project management experience will show a higher level of actual performance during the exercise than those with less project management experience will.
Hypothesis 6 (H6): Participants who spend more effort in the exercise will show better actual performance than participants who spent less effort during the exercise will.

Finally, we evaluated the effects of PMKL assessed in both pre- and post-exercise surveys on actual performance of the exercise. The PMKL assessed in the pre-exercise survey represents the PM knowledge before starting the game (prior-PMKL), while the PMKL assessed in the post-exercise survey represents the PMKL achieved because of the exercise (post-PMKL). We believe that higher perceptional knowledge positively affects the actual performance of the exercise, and higher performance leads to higher perceived PMKL. Hence, we expected that those who showed higher prior-PMKL would be likely to have better performance than others did (H7), and those who showed higher performance would achieve higher post-PMKL (H8).

Hypothesis 7 (H7): Participants who start the exercise with high level of project management knowledge are likely to achieve a higher level of actual performance than others are during the exercise.
Hypothesis 8 (H8): Participants who achieve higher level of performance during the exercise are likely to achieve higher level of PMKL than others are.

Analysis and Results

We assumed that the populations being sampled were approximately normal. Based on this, we used parametric tests such as *t* test and ANOVA. The central limit theorem (CLT) provides enough of a theoretical base for this study because it states that the sample "means" are approximately normally distributed regardless of original distribution if sample sizes are greater than 5 or 10 per group (Norman, 2010). The sample size per group varies between 16 and 25 in this study. To evaluate H1, we assessed the first 14 questions in Table 1 in both pre- and post-exercise questionnaires to calculate the pre- and post-exercise knowledge levels—pre-KL and post-KL, respectively. Then, we evaluated whether pre-KL was equal to the post-KL for each of the 14 questions using the paired *t*-test statistics. Based on these results, we evaluate participants'

Table 3. PM Knowledge Improvement Between Pre- and Post-Exercises (H1).

Questions	Pre-KL	Post-KL	*t* value	95% CI	*p* value
1. Scope management	3.5	4.2	4.76	[0.368, 0.908]	.000**
2. Time management	3.7	4.2	2.67	[0.133, 0.846]	.008**
3. Cost management	3.4	4.1	4.29	[0.373, 1.031]	.000**
4. Quality management	3.3	4.0	3.94	[0.312, 0.965]	.000**
5. Human resource management	3.2	3.7	2.85	[0.162, 0.944]	.007**
6. Risk management	3.5	3.7	1.01	[−0.189, 0.572]	.316
7. Communication management	3.6	4.2	3.60	[0.291, 1.028]	.001**
8. Procurement management	3.0	3.5	2.67	[0.131, 0.933]	.010**
9. Integration management	3.2	3.9	4.82	[0.409, 0.995]	.000**
10. Scope management	3.5	4.2	3.73	[0.313, 1.049]	.001**
11. Initiating process	3.6	4.3	4.40	[0.358, 0.961]	.000**
12. Project planning process	3.6	4.3	3.80	[0.301, 0.976]	.000**
13. Project executing process	3.5	4.0	3.24	[0.193, 0.828]	.002**
14. Monitoring and control process	3.2	4.1	4.88	[0.525, 1.262]	.000**

Note. PM = project management; Pre-KL = pre-exercise knowledge levels; Post-KL = post-exercise knowledge levels; CI = confidence interval.
**$p < .01$.

project management knowledge before the exercise (prior-PMKL) and after the exercise (post-PMKL).

Table 3 is a display of the average of pre- and post-exercise knowledge, its paired two-tailed *t* statistics (*t* value for difference between post-KL and pre-KL), the 95% confidence interval, and associated *p* value for each of the 14 questions. All were significant (p value < .01) except risk management, indicating that these differences are statistically significant. Scope, cost, quality, and integration management are the areas where participants believed that they had the highest improvement. Participants also believed that their perceived knowledge about initiation and monitoring and control process improved greatly. We conducted a correlation analysis that showed a highly positive correlation between pre-KL and post-KL (Pearson correlation coefficient .744 with p value < .002). Therefore, we conclude that according to participant perceptions, significant PMKL improvement occurred after the simulation training exercise. In other words, we can conclude that post-PMKL is higher than prior-PMKL.

In the case of risk management, SimProject does not follow a typical risk management procedure described in PMBOK® where a project manager needs to identify and analyze risk factors, and to plan risk responses. Instead, it recommends that participants keep financial reserve for all risks based on estimated risk probability. Hence, we believed that this simple risk management procedure in SimProject created a perceptional gap between what participants learned from PMBOK® and what they observed in SimProject.

To evaluate H2, we classified participants into three different PM experience levels using the answers in question number 15 in Table 1. Then, we evaluated the effects of PMEL on PMKL assessed in the pre-exercise survey. However, the survey analysis

Table 4. PMEL and PMKL in Pre-Exercise (H2).

	Sample analysis			Two-sample *t*-test results		
Hypothesis	PMEL	No. of samples	Avg-Pre-KL	*t* value	95% CI ub	*p* value
H2	Low/medium	22/25	3.23/3.583	−1.39	0.077	.087*

Note. PMEL = project management experience level; PMKL = project management knowledge level; Pre-KL = pre-exercise knowledge levels; CI ub = upper bound confidence interval.
*$p < .1$.

Table 5. PMEL and Knowledge Improvement Rate After Exercise (H4).

	Sample analysis			Two-sample *t*-test results		
Hypothesis	PMEL	No of samples	Avg-KL difference	*t* value	95% CI lb	*p* value
H4	Low/medium	22/25	0.802/0.434	1.42	−0.040	.069*

Note. PMEL = project management experience level; CI lb = lower bound confidence interval.
*$p < .1$.

showed that no one indicated oneself as an individual with high PM experience. Instead, as Table 4 shows, 22 and 25 participants classified themselves as personnel with low PMEL and medium PMEL, respectively. The average knowledge level across all 14 questions (Avg-Pre-KL) for the low PMEL was 3.23 while for the medium PMKL, it was 3.583. The two-sample *t* test supported that the participants with more PMEL had more PMKL at the 10% significance level (*p* value = .087) with its 95% upper bound confidence interval (95% CI ub). H3 requires the same statistical procedure, but with the post-exercise survey data. However, it was not supported. We found no statistical evidence that those with more PM experience obtain higher PMKL after the exercise. In other words, before the exercise, those with higher experience perceived that they had higher PMKL. However, the same perception was not statistically supported after the exercise.

To evaluate H4, we computed the composite index for PMKL for each participant using the pre-KL and post-KL, generating the pre- and post-composite PMKL indices, respectively. A composite PMKL index is the mathematical average of all PMKLs measured by pre-KL across 14 questions in Table 1. Then, we computed the difference between the post-composite PMKL index and the prior-composite PMKL index for each experience level. The difference represents the PMKL improvement for that specific PM experience level. Finally, we determined whether the PMKL improvement for the low PMEL was significantly larger than that for the medium PMEL. As Table 5 shows, the average of composite PMKL index difference (Avg-KL difference) for the low level PMEL is 0.802, whereas the same value for the medium level PMEL

Table 6. Pre-Exercise PMKL and Actual Exercise Performance (H7).

Performance metric	Sample analysis			Two-sample *t*-test results		
	Pre-PMKL	No of samples	Average metric	*t* value	95% CI lb	*p* value
Time	Low/high	24/16	11.206/11.375	−0.42	0.523	.340
Cost	Low/high	24/16	US$52,965/ US$48,322	2.01	740	.026*

Note. PMKL = project management knowledge level; CI lb = lower bound confidence interval.
*$p < .1$.

is 0.434. Statistical evidence shows that participants with low PMEL achieved greater PMKL improvement at the 10% significance level (*p* value = .069).

H5 and H6 are analyses of the effects of PMEL and effort spent in the exercise by each participant on actual exercise performance, respectively. Two performance measures were used to evaluate the actual performance of the simulation exercise: project cost spent to complete the project (Cost) and project duration taken to complete the project (Time). We captured these two measures through two questions in Section 5 of Table 2. The average time and cost for the low experience level were 11.26 weeks and US$50,190, respectively, whereas the same values for the medium experience level were 11.28 weeks and US$51,859. The two-sample *t*-test result did not support that those participants with higher level PM experience achieve better performance in terms of both metrics (H5). We attempted to measure the actual effort spent by a participant in two different ways: the number of repetitions of the simulation game, and total hours spent to complete the simulation exercise. However, we eventually chose the total hours spent because the number of repetitions did not represent the actual effort accurately; as the duration of each repetition may vary from participant to participant—some participants fully explored the game regardless of their performance whereas other frequently repeated it whenever they faced poor performance without reaching the end of the game. Therefore, we concluded that the larger number of repetitions does not necessarily mean greater effort. Similar to previous factors, we classified the actual total hours into two levels: low (≤3 hours) and high (otherwise). The average project duration (Time) and project cost (Cost) for the low effort level were 11.21 weeks and US$48,955, respectively, while those of the same metrics for the high effort level were 11.33 weeks and US$52,280, respectively. As indicated by these average data, H6 was not supported, indicating that no statistical evidence was found showing that participants who spend more effort achieve better performance.

Table 6 shows the statistical results of H7 to evaluate whether pre-exercise PMKL affects actual performance of the exercise or not, while Table 7 is a summary of the statistical results concerning whether actual performance affects post-exercise PMKL or not (H8). Again, we used the composite PMKL index and classified participants into two levels according to their performance of the exercise in terms of time and cost. We should note that data were cleaned because some participants did not provide specific performance metric values. That is why only 40 samples are considered in

Table 7. Actual Exercise Performance and Post-Exercise PMKL (H8)..

	Sample analysis			Two-sample *t*-test results		
Performance metric	Performance	No of samples	Avg. post-PMKL	*t* value	95% CI ub	*p* value
Time	Low/high	24/16	3.745/4.318	2.23	0.162	.017*
Cost	Low/high	20/20	3.777/4.313	2.35	0.162	.012*

Note. PMKL = project management knowledge level; CI ub = upper bound confidence interval.
$^{*}p < .1$.

Table 8. Correlation Matrix Between Effort and Actual Performance Metrics.

	Hours spent	Repetition	Time	Cost	Pre-KL	Post-KL
Hours spent	1	−.018	−.119	.050	−.206	−.032
Repetition		1	−.025	−.097	−.326*	−.198
Time			1	.312*	−.051	−.248*
Cost				1	−.282*	−.129*
Pre-KL					1	.559**
Post-KL						1

Note. Pre-KL = pre-exercise knowledge levels; Post-KL = post-exercise knowledge levels.
$^{*}p < .1$. $^{**}p < .01$.

Tables 6 and 7. As shown in Table 6, the acceptance of H7 is mixed between performance metrics. For example, we found a strong statistical evidence indicating that participants who began the exercise with higher PMKL achieve higher performance in terms of Cost (*p* value = .026). However, we found no support in terms of Time. The significance of pre-PMKL on cost was also observed by an analysis of variance (ANOVA) test using pre-PMKL as a factor and cost as a response. The plot of residual versus pre-PMKL did not show any significant variability, so the residuals are probably homoscedastic with respect to pre-PMKL. The histogram of the residuals followed the expected bell-shaped normal curve, and we could not observe any outlier. The normal probability plot showed that residuals fall along an approximately straight line. The result of ANOVA also supported that pre-PMKL was a significant factor for cost (*p* value = .053).

To evaluate H8, we classified time and cost into two groups (low- and high-performance groups) based on 50% percentiles, respectively—11 weeks for time and US$49,063 for cost. Then we calculated the composite post-PMKL values in Avg. post-PMKL column as seen in Table 7. Participants who achieved better performance also achieved higher PMKL after the exercise (*p* value = .017 for time) and (*p* value = .012 for cost). From Tables 6 and 7, we can observe that cost is more sensitive to post-PMKL than time.

Table 8 shows Pearson correlation coefficient values among many factors discussed. While many factors were independent with each other, we can observe a strong

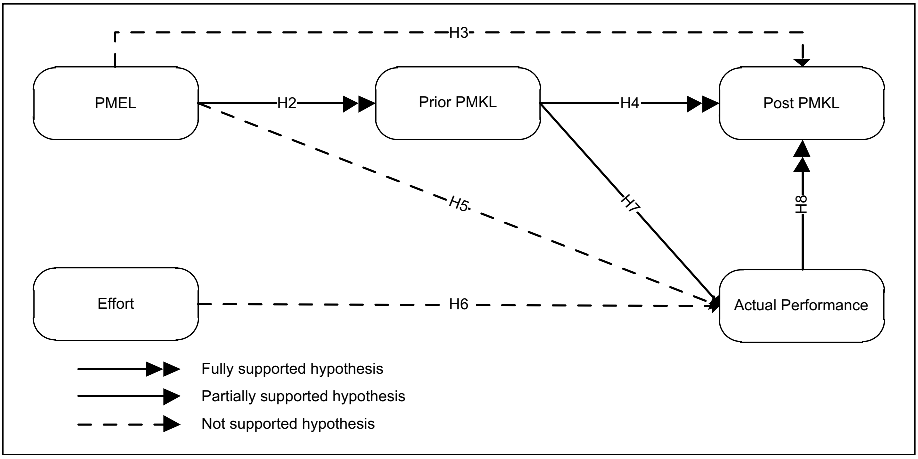


Figure 4. Relationship among hypotheses.
Note. PMEL = project management experience level; PMKL = project management knowledge level.

positive correlation between the prior-KL and the post-KL. Both prior-KL and post-KL are composite a PMKL index computed from pre- and post-exercise questionnaires, respectively. This positive correlation along with the acceptance of H1 indicates that those with more PMKL before the exercise maintain higher level of PMKL after the exercise. A significant positive correlation was also present between cost and time. We also noted that both prior-KL and post-KL indices have a negative correlation with the effort-related factors (hours spent and the number of repetition) and the performance-related factors (project time and cost) as expected. The negative correlation between prior-PMKL and cost is significant at the 10% significance level, but the correlation between the prior-PMKL and time was not, and this is aligned with the results in Table 6 for H7. However, both correlations between post-PMKL and two performance metrics—cost and time—were significant at the 10% significance level, and this supports the conclusion in Table 7 for H8.

Discussion

The results that we present in this research provide many useful insights on the use of project management simulation as a training tool. Four hypotheses were supported (H1, H2, H4, and H8) and three hypotheses were not supported (H3, H5, and H6), while one hypothesis was partially supported (H7). Figure 4 provides an overall view of relationship of hypotheses where solid two-headed and one-headed arrows represent a fully supported hypothesis and a partially supported one, respectively, while a dotted arrow denotes an unsupported hypothesis. The fully supported H1 is not displayed.

First, based on the acceptance of H1, overall, the simulation training exercise is considered an effective tool to improve perceptional project management knowledge;

this conclusion is aligned with conclusions from other previous research (Cano & Sáenz, 2003; McCreery, 2003; Zwikael & Gonen, 2007). The acceptance of H2 indicates that participants with more PMEL are likely to have higher perceived PMKL. These participants begin the simulation exercise with higher conceptual PMKL compared with those participants with less PMEL. The result is consistent with that in McCreery (2003). The acceptance of H4 indicated that the exercise was more effective to the participants with less PM experience. New learners were likely to have higher motivation than others did; this may positively affect their learning, and this result is aligned with McCreery. In addition to the motivation, this may imply that those with a higher pre-PMKL have a smaller knowledge gap to fill.

Although PMEL is important in establishing pre-PM knowledge, its effects on the post-PM knowledge establishment were not directly supported (H3), indicating that the simulation game affected participants' judgment during the exercise. We believe that the actual performance of the exercise is a good representation of the educational value of the exercise. According to this research, the actual performance is mostly affected by the prior-PMKL (H7), neither by the previous project management experience (H5) nor by the effort (time) spent in the training (H6). Actual performance directly affected the post-PMKL (H8), which is well aligned with Mayer et al. (2011).

The discussion of lessons to be learned, as well as sharing individual experiences, has been incorporated into simulation and gaming literature under the umbrella of debriefing for years. The role of debriefing within the topics of learning, knowledge, and understanding has been analyzed extensively from different perspectives, including philosophy (Willy, 2010), mechanics of learning (Peters & Vissers, 2004; Petranek, 2000), and psychology (Jones, 2004), among others. In this study, part of the post-exercise questionnaire consisted of questions relating to the experience of using the software and playing the game. Figure 5 shows the qualitative feedback from participants. Participants evaluated that overall the simulation exercise was thought-provoking and useful in their PM learning and practice, and it was appropriately challenging—participants rated its complexity as 3.7/5.0. All of this feedback will be taken into account for improving the exercise in the following years.

Conclusions and Future Research

In this article, we investigated a PM simulation training exercise using the SimProject simulation software. We tested the exercise on 47 graduate students in their project management classes for 2 years where most students were working professionals with 1 to 5 years' experience in science and engineering. Unlike previous research, we used a single-player simulation game rather than a multiple-player game to assess accurately the perception and performance of an individual without interference from team interaction.

The overall results show that the exercise significantly contributed to the participants' perceptional knowledge in almost all project management areas. The prior-project management experience level (PMEL) appeared to be an important factor for prior-project management knowledge level (PMKL) establishment and the prior-PMKL strongly supported the post-PMKL. While the prior-PMKL directly supported

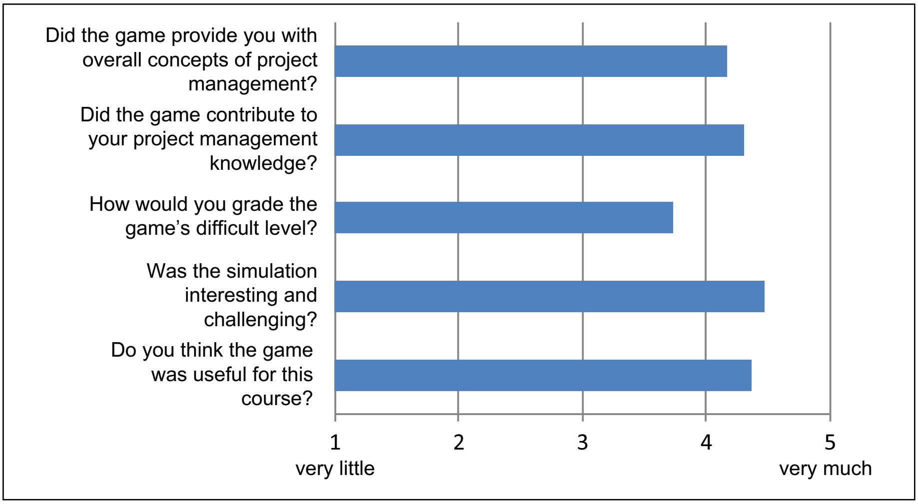


Figure 5. Overall feedback questionnaire results.

actual performance and post-PMKL, the PMEL indirectly supported actual performance and post-PMKL through prior-PMKL. We did not find any evidence that effort supported actual performance. It is also strongly supported that participants with high performance establish strong perceptional knowledge after the exercise. Based on this analysis, the prior-PMEL and PMKL seemed to be important factors for participants' post-exercise perception and actual performance, and the pre-experience was an important factor for prior knowledge. However, in this study, we did not identify whether any other factors affecting the prior knowledge in addition to the prior experience were present. Regardless of these hypothesis analyses, the qualitative analysis showed that participants' overall satisfaction rate was relatively high. Based on this statistical and qualitative analysis, we claim that the simulation exercise is useful for project management training.

This study has several limitations. Just as other studies using statistical methods, this study may reflect only limited aspects of participant behavior and interaction with the project management exercise. The participant sample is a major drawback of this study because it is only collected from one university. Thus, it possibly biased the findings of this study, and more research with diversified sampling domains is needed for generalization. We did not consider many other potentially important factors such as the personality, learning style, instructional strategy, and area of expertise of a participant, among other factors. The lack of these factors may have affected the findings, limiting the generalization of this study.

A confirmatory factor analysis using the structural equation model (SEM) with these potentially important factors may provide analysis that is more detailed and is considered an immediate future research area. The validation of this study in a real life environment may also be considered another future research item. This validation may be performed by comparing the results of this study with the performance of participants in the actual projects in which they are involved.

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