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Students' View on Potential of a Project-Based Simulation Game for Construction Education

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ABSTRACT

This study was carried out to assess the potential of a virtual project-based simulation game in educating construction students, form their own perspective. For this purpose, a project-based simulation game, named Skyscraper Simulator, which focuses on construction management, was tested by 135 undergraduate construction students. After playing, the participants filled out a questionnaire to evaluate the game's effectiveness. For assessing their responses, quantitative methods were used. The results indicate that from the viewpoint of the students, a virtual project-based simulation game has positive effect on construction education, and so it can be used as a supplementary tool in educating construction students at the undergraduate level.

Keywords: Construction, Education, Project-based, Self- assessment, Simulation, Virtual

I. INTRODUCTION

Games and simulations have been used as a part of education and learning methods (Ruben 1999). During recent years, game-based learning has attracted more attention (Bodnar et al. 2016). Several features of games allow them to be used as learning tools (Fig.1) (Pariafsai 2016a). As well as learning affordances, games positively affect conceptual understanding, problem solving, and critical thinking (Dabbagh et al. 2016). Educational games increase motivation, interest, and engagement of students (POSSA 2011). Game-based activities also improve students' learning and attitudes in undergraduate engineering classrooms (Bodnar et al. 2016). For instance, using an online game during a lecture at Master's level can be both efficient and enjoyable for students (Ebner and Holzinger 2007).

Furthermore, using educational simulations has considerably increased recently (Kincaid et al. 2001). Fig. 1 indicates the reasons of their importance to the field of education (Pariafsai 2016a, Kincaid et al. 2003). Simulations allow learners to visualize situations which might encounter on the job (Hale Feinstein, Mann, and Corsun 2002), thereby developing students' awareness of real world issues and understanding of course subjects (Philpot et al. 2005, Crown 2001, Hirose, Sugiura, and Shimomoto 2004). When advanced visualization tools are used, students can understand construction projects and plans much better (Messner et al. 2003). Without real costs or risks, simulations expose students to realistic experiences (Nikolić 2011).

Simulation games as active learning tools can develop generic professional practice skills of construction students (Agapiou 2006, Scott, Mawdesley, and Al-Jibouri 2004). So far, some simulations developed for teaching construction processes including planning, schedule review, resource allocation, risk analysis, and site planning (Nikolic, Jaruhar, and Messner 2011). Moreover, the effectiveness of the project-based methods as an alternative pedagogical model in academic environments has been proven (Baş 2011). In construction education, the most efficient methods should be exploited so as to prepare construction students to join the workforce. In order to achieve this goal, the potential of new educational models should be evaluated. Accordingly, this research was done to assess the effectiveness of a virtual project-based simulation game named Skyscraper in construction education.

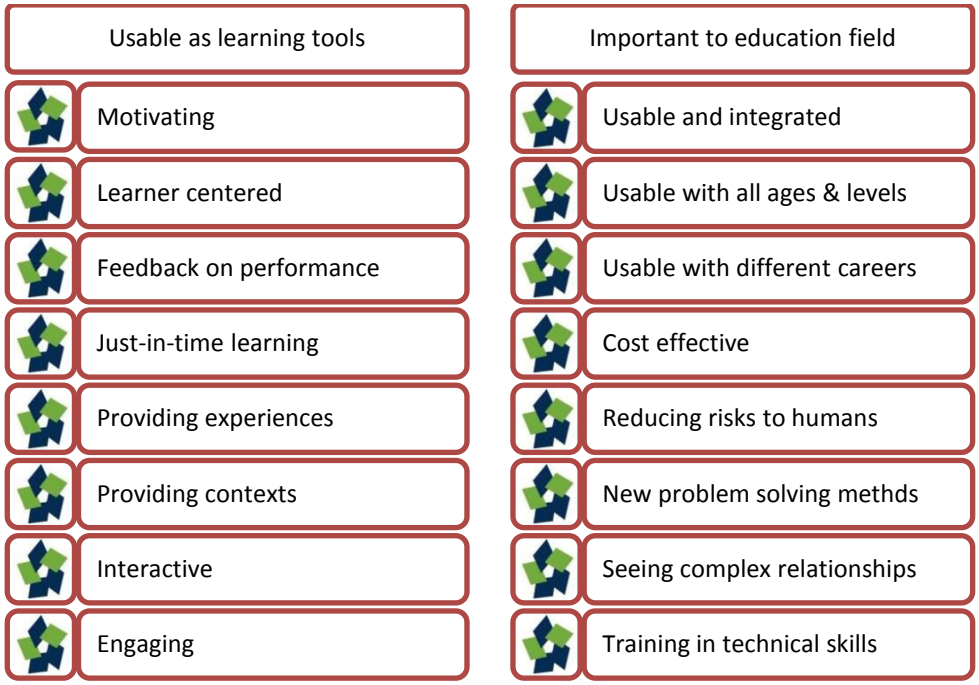

Figure 1: Features of simulations as pedagogical tools

II. METHODS AND MATERIAL

This research aimed to assess the effectiveness of a project-based simulation game in construction education through the eyes of construction students. For this purpose, Skyscraper Simulator, which includes the subject areas typical for construction management curriculum (Pariafsai 2013), was selected. Skyscraper Simulator is a virtual project-based simulation game which directs players on how to manage construction of skyscrapers. The players should manage each activity and complete all related sub-activities. They should buy required equipment, employ needed personnel, and assign them to each activity. The players' decisions affect both cost and duration of projects. Wrong decisions may also result in stopping the construction process. The outcomes of the decisions can be seen through an indicator which shows the time and funds throughout the game. While playing, players watch the gradual completion of projects.

This study was designed into two sections: playing the game and doing a survey. 135 construction students at the undergraduate level partook in the test (Pariafsai 2016b). Every participant managed the construction of one skyscraper from the beginning to the end. After finishing the construction, they completed a questionnaire and answered questions about their age, gender, years of experience in construction, and whether they have passed any courses in construction management. They also responded to a set of questions including:

1. Playing games:
   - Using computer for playing games
   - Time spent on games per day

2. Intrinsic properties of the game:
   - Speed of the game
   - Satisfaction of graphical appearance
   - Complexity of the game
   - Being vague why decisions are right or wrong

3. Simulating effects:
   - Imagining a real construction site
   - Teaching the construction process
   - Change in thoughts on the construction site

4. Knowledge and skill development:
   - Using instructions while playing
   - Decision-making positions as project manager
   - Increase in analysing ability

5. Simulation games' potential:
   - Increase in traditional pedagogical efficiency
   - Increase in class efficiency

- Such games in preference to lectures
- Necessity of experience through such games

III. RESULTS AND DISCUSSION

This research hypothesized that a project-based simulation game is an effective learning tool in the eyes of students with limited previous education in construction. 135 undergraduate construction students including 66 females (48.9%) and 69 males (51.1%) took part in the test (Pariafsai 2016e). The mean experience of the participants in construction was less than 1 year ($\mu = 0.789$, $\sigma = 1.9326$) while 77% of them had no experience in construction (Pariafsai 2016d). Moreover, 68.1% of the students had some previous knowledge in project management since they had passed courses relevant to project management (Pariafsai 2016c). After completion of the game, the students answered the hypothesis question, i.e. the effectiveness of a simulation game in construction education. In order to assess the students' answers, a five-point Likert scale was used to quantify their opinions. The Likert scale provided values 1, 2, 3, 4 and 5 respectively for not at all, just a little, somewhat, a lot and a great deal.

Playing Games

In one question, participants rated to what extent they use personal computer, cell phone, or the Internet for playing games. Table 1 presents the percentage of each level of the five point Likert scale. The responses mean and standard deviation ($\mu = 3.622$, $\sigma = 1.2270$) indicate the participants reported that they use personal computer, cell phone, or the Internet for playing games between somewhat and a lot. 22.2% of students stated that they either not at all or just a little use personal computer, cell phone, or the Internet for playing games (4.4% and 17.8% respectively) whereas 57. 1% of them reported that they play games using personal computer, cell phone, or the Internet either a lot or a great deal (25.2% and 31.9% respectively) (Fig. 2). Therefore, 77.8% of the participants reported that at least somewhat, they use personal computer, cell phone, or the Internet for playing games.

In another question, the participants rated how time per day they spend at playing computer games. Table 1 presents the percentage of each level for all students. The responses mean and standard deviation ($\mu = 2.711$, $\sigma = 1.1836$) indicate that the participants rated spent time per day at playing computer games nearly somewhat. The highest percentage (30.4%) belongs to the level somewhat (Fig. 2). Moreover, 17.0% of students reported that they spend no time at playing computer games whereas 54.9% the students reported that they spent at least some time per day at playing computer games. This means over half of the students play computer games at least some time per day.

Table 1: Rating Responses to Playing Games Questions

	PC, Cell phone, Internet for Game	Game Time per Day
Not at all	4.4%	17.0%
Just a little	17.8%	28.1%
Somewhat	20.7%	30.4%
A lot	25.2%	15.6%
A great deal	31.9%	8.9%
Mean	3.622	2.711
Std. Deviation	1.2270	1.1836

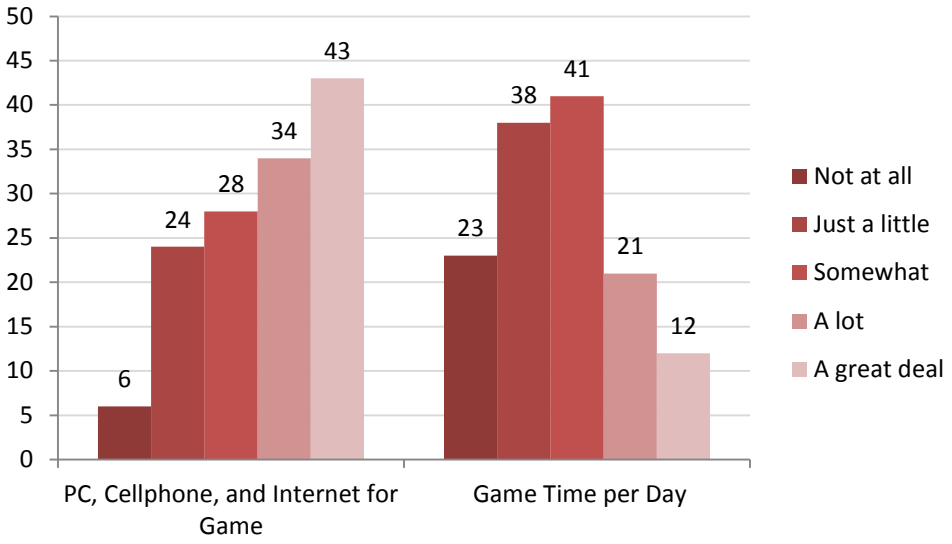

Figure 2: Percentage distribution for responses to playing games questions

Intrinsic Properties of the Game

In one question, the participants were asked to rate the speed of the game. The responses indicate that over half of the players (53.3%) rated the speed controllable. The second high percentage (35.6%) belongs to normal (Fig. 3). Only 11.1% of the students stated that it was too low or too high (8.9% and 2.2% respectively). In other words, the cumulative percentage of the options controllable and normal (88.9%) is higher than that of the options too low or too high (11.1%), which means most players didn't have any problem with the speed of the game while playing.

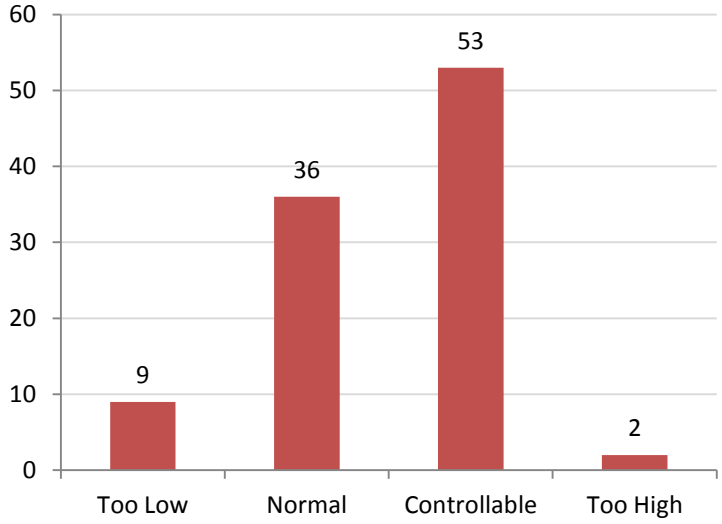

Figure 3: Percentage distribution for the game's speed

In another question, the participants rated the graphical quality of the game. Table 2 presents the percentage of each level for all students. The responses mean and standard deviation ($\mu = 2.904$, $\sigma = 1.0850$) indicate that on average, the participants rated the graphical quality of the game as somewhat. The highest percentage (35.6%) belongs to the level somewhat (Fig. 4). Moreover, 35.6 % of students reported that the graphical quality satisfied them either "not at all" or "just a little" whereas 28.9% of students mentioned the graphical quality of the game

was satisfying either a lot or a great deal (21.5% and 7.4% respectively). This means that most students (71.2%) were not very satisfied with the graphical appearance of the game.

Participants also rated the complexity of the game. Table 2 presents the percentage of each level of the five point Likert scale. The responses mean and standard deviation ($\mu = 2.867$, $\sigma = 0.8961$) indicate the participants reported that the game was somewhat complex. 80.0% of students stated that the game was not really difficult (Fig. 4) whereas in the eyes of the rest it was complex either a lot or to a great degree (15.6% and 4.4% respectively). Therefore, only for 20.0% of the participants, the game was really difficult.

Participants also rated to what extent it was vague why the decisions were wrong. Table 2 presents the percentage of each level of the five point Likert scale. The responses mean and standard deviation ($\mu = 3.126$, $\sigma = 0.9957$) indicate that the reasons for which the decisions were considered wrong were vague to some degree. 73.3% of students stated that the reasons why they made a wrong decision were unclear at least somewhat (Fig. 4) whereas 23.7% of them rated the ambiguity of the reasons as just a little. Furthermore, only 3.0% of them stated that the reasons were completely clear. Therefore, for most participants (97.0%) the reasons of making a wrong decision were not completely clear.

Table 2: Results of Rating the Game's Intrinsic Properties

	Graphical Quality	Game Complexity	Reasons Vagueness
Not at all	10.4%	5.2%	3.0%
Just a little	25.2%	27.4%	23.7%
Somewhat	35.6%	47.4%	42.2%
A lot	21.5%	15.6%	20.0%
A great deal	7.4%	4.4%	11.1%
Mean	2.904	2.867	3.126
Std. Deviation	1.0850	0.8961	0.9957

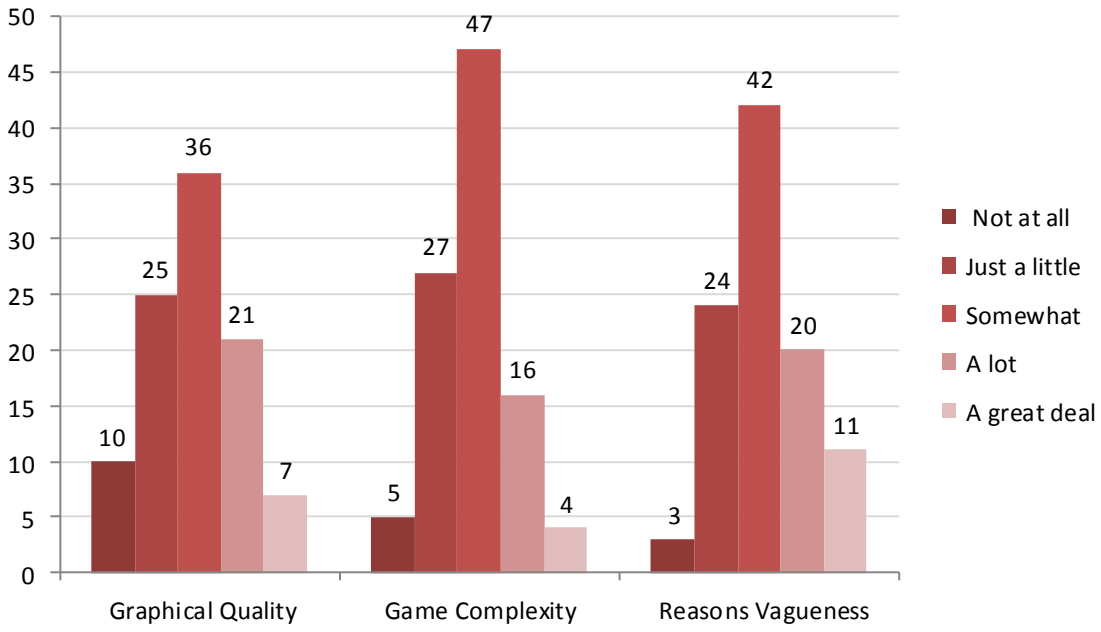

Figure 4: Percentage distribution for the game's intrinsic properties

Simulating Effects

In the other question, participants were asked to rate to which extend the game make them imagine themselves working on a real construction site. Table 3 presents the percentage of each level of the five point Likert scale. The responses mean and standard deviation ($\mu = 3.33$, $\sigma = 1.0294$) indicate that the participant imagined themselves on the construction site while playing to the degree between somewhat and a lot. 81.5% of the students stated that while playing they imagined themselves working on a real site at least somewhat (Fig.

5) only 18.5% of them reported that they imagined themselves on a real site either "not at all" or "just a little". Therefore, playing the game helped most students (81.5%) imagine that they were working on a real construction site.

Additionally, the participants rated how efficient the game was as a tool for teaching the construction process in the real world. In Table 3, the percentage of each level is shown. The mean and standard deviation of responses were $\mu = 3.585$ and $\sigma = 0.7470$. The highest percentages belong to the levels somewhat and a lot (43.7% and 42.2% respectively). Further, only 3.7% of the students stated that it was nearly inefficient for learning the construction process (Fig. 5) whereas 96.3% of them reported that playing the game was at least somewhat useful for learning the construction process. In other words, most students (96.3%) believed that the game was an efficient tool for teaching the construction process.

Participants were also asked to rate how much the game change their thoughts on the construction site. Table 3 shows the percentage of each level of the five Likert scale. The responses' mean and standard deviation ($\mu = 3.348$, $\sigma = 0.8580$) indicate that the game changed their perception of the construction site to a degree between somewhat and a lot. The highest percentage (43.7%) relates to the level "somewhat". In addition, only 12.6% of the students rated the change in their perception either "not at all" or "just a little" (3.0% and 9.6% respectively). The cumulative percentage of the levels somewhat, a lot, and a great deal (87.4%) indicates most players thought that playing the game changed their perception of the construction site at least somewhat.

Table 3: Results of Rating the Game's Simulating Effects

	Imagining One on the site	Construction Process	Perception Change
Not at all	5.9%	0.7%	3.0%
Just a little	12.6%	3.0%	9.6%
Somewhat	34.8%	43.7%	43.7%
A lot	35.6%	42.2%	37.0%
A great deal	11.1%	10.4%	6.7%
Mean	3.333	3.585	3.348
Std. Deviation	1.0294	0.7470	0.8580

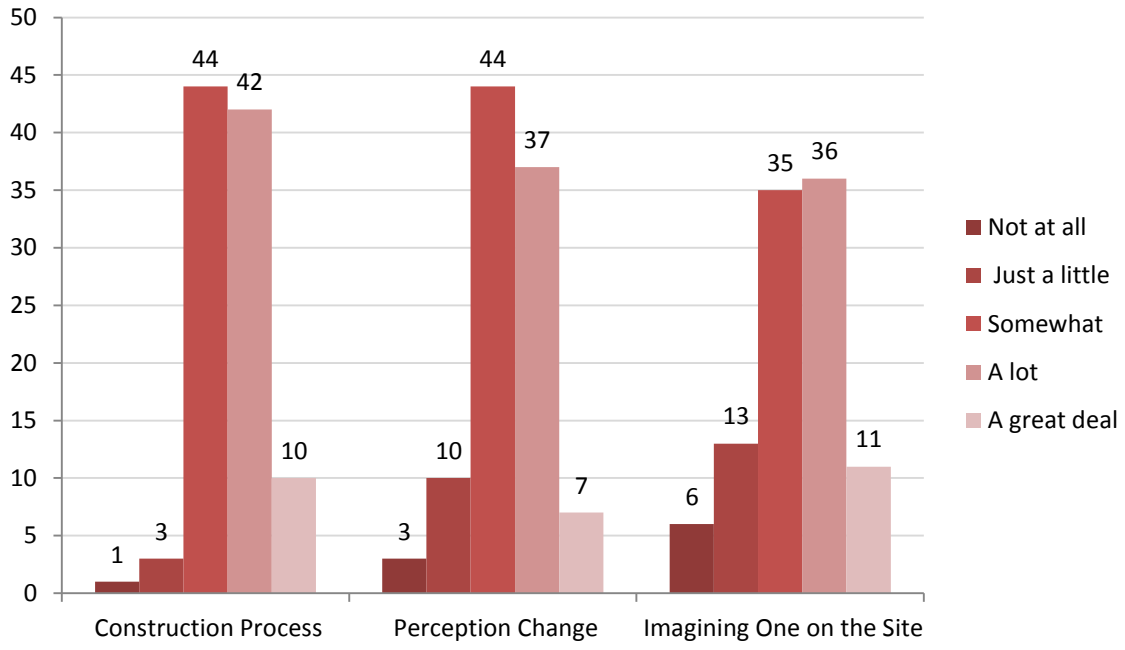

Figure 5: Percentage distribution for the game's simulating effects

Knowledge and Skill Development

The players were asked to rate how much they used what they learned from instructions, while playing. According to the responses mean and standard deviation ($\mu = 3.230$, $\sigma = 1.0923$), the participants rated the use of instructions to a degree between somewhat and a lot.

Only 8.9% of students stated that they never used what they learn from instructions (Fig. 6) In addition, the cumulative percentage of the levels somewhat, a lot and a great deal is 78.5% (Table 4) which means that most students considerably used what they learned from instructions.

In another question, the participants also rated the extent to which the game put them in positions to make decisions as a project manager. Table 4 shows the percentage of each level of the five Likert scale. The responses mean and standard deviation ($\mu = 3.778$, $\sigma = 0.9115$) indicate that they rated the extent to which the game placed them in decision-making positions between somewhat and a lot. The level a lot obtained the highest percentage (44.4%). In addition, only 8.2% of the students rated the extent either "not at all" or "just a little" (1.5% and 6.7% respectively) (Fig. 6) whereas over half of the students (65.9%) reported that the game put them in such positions either a lot or a great deal (44.4% and 21.5% respectively). Furthermore, 94.0% of the students rated the extent at least somewhat.

Moreover, students rated how much the game increased their analysis ability. Table 4 shows the percentage of each level. The responses mean and standard deviation ($\mu = 3.674$, $\sigma = 0.8180$) (Table 4) indicates that they believed that the game improved their analysis ability between somewhat and a lot. The highest percentage belongs to the level a lot (44.4%) (Fig. 6) and only 5.9% of the students found it either not at all or just a little helpful in increasing such an ability (0.7% and 5.2% respectively) whereas over half of them (59.2%) reported that it was either a lot or a great deal useful for increasing the ability to analyze (44.4% and 14.8% respectively). Moreover, the results indicate that 91.8% of students believed that the game developed their analysis ability at least somewhat.

Table 4: Results of Rating Knowledge & Skill Development

	Using Instructions	Decision-Making Positions	Analysis Ability
Not at all	8.9%	1.5%	0.7%
Just a little	12.6%	6.7%	5.2%
Somewhat	36.3%	25.9%	34.8%
A lot	31.1%	44.4%	44.4%
A great deal	11.1%	21.5%	14.8%
Mean	3.230	3.778	3.674
Std. Deviation	1.0923	0.9115	0.8180

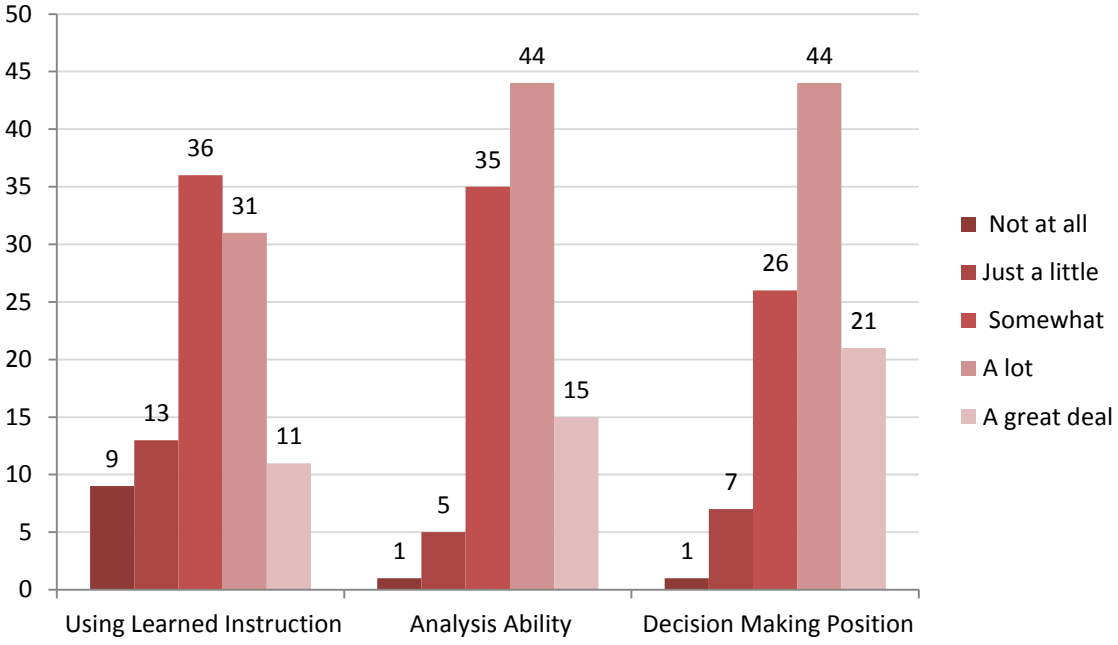

Figure 6: Percentage distribution for knowledge & skill development

Simulation Games' Potential

The players were also asked to rate how much computer simulation games increase the efficiency of traditional pedagogical methods. Table 5 presents the percentage of each level of the five Likert scale. According to the responses mean and standard deviation ($\mu = 3.874$, $\sigma = 0.8052$), they believed that such games enhance the

efficiency of the traditional methods nearly a lot. The highest percentage (46.7%) belongs to the level a lot (Fig. 7). Only 6.7% of students stated that computer simulation games improve the efficiency of traditional pedagogical methods either not at all or just a little (0.0% and 6.7% respectively) whereas 70.4% of them reported that such games enhance the traditional methods' efficiency either a lot or a great deal (46.7% and 23.7% respectively). The cumulative percentage of the levels somewhat, a lot and a great deal (93.4%) indicates that most students agreed that the efficiency of traditional pedagogical methods can be improved at least somewhat by means of computer simulation games.

In another question, the participants were asked to rate to which extent computer simulation games enhance class efficiency. The responses mean and standard deviation ($\mu = 3.874$, $\sigma = 0.8051$) indicate that they rated the efficiency improvement between nearly a lot. The highest percentage (47.4%) belongs to the level "a lot" (Fig. 7). None of the students rated it as "not at all" (Table 5) whereas 69.6% of them reported that computer simulation games could increase class efficiency either a lot or a great deal (47.4% and 22.2% respectively). Moreover, the cumulative percentage of the levels a lot and a great deal (69.6%) is higher than that of the levels just a little and somewhat (30.3%), which means over half of the players agreed that the class efficiency could be improved to a great degree by using computer simulation games.

The participants were also rated how much they preferred learning through educational computer games compared to learning through listening to lectures. The responses mean and standard deviation ($\mu = 3.756$, $\sigma = 0.9809$) indicate that the participants preferred educational computer games to listening to lectures. Only 1.5% of students stated that they preferred listening to lectures to the games (Fig. 7). In addition, over half of the students (60.7%) reported that they preferred either a lot or a great deal to learn by means of the games than listening to lectures (34.8% and 25.9% respectively) (Table 5). The results indicate that most students (90.3%) preferred at least somewhat to learn by playing instead of studying.

In another question, the participants rated how necessity the experience through computer simulation games is in learning from their perspective. Table 5 presents the percentage of each level for all students. The responses mean and standard deviation ($\mu = 3.607$, $\sigma = 0.8902$) indicate that the participants rated such necessity between somewhat and a lot. The highest percentage (37.8%) belongs to the level somewhat and a lot (Fig. 7). Moreover, only 8.2% of students rated the necessity either "not at all" or "just a little" (1.5% and 6.7% respectively) whereas over half of the students (54.1%) agreed with the necessity of experience through computer simulation (37.8% and 16.3% respectively). This means that most students (91.9%) believe in the positive impact of experiencing by means of computer simulation games on learning.

Table 5: Results of Rating Simulation Pedagogical Potential

	Methods Efficiency	Class Efficiency	Game vs. Lecture	Necessity
Not at all	0.0%	0.0%	1.5%	1.5%
Just a little	6.7%	4.4%	8.1%	6.7%
Somewhat	23.0%	25.9%	29.6%	37.8%
A lot	46.7%	47.4%	34.8%	37.8%
A great deal	23.7%	22.2%	25.9%	16.3%
Mean	3.874	3.874	3.756	3.607
Std. Deviation	0.8052	0.8051	0.9809	0.8902

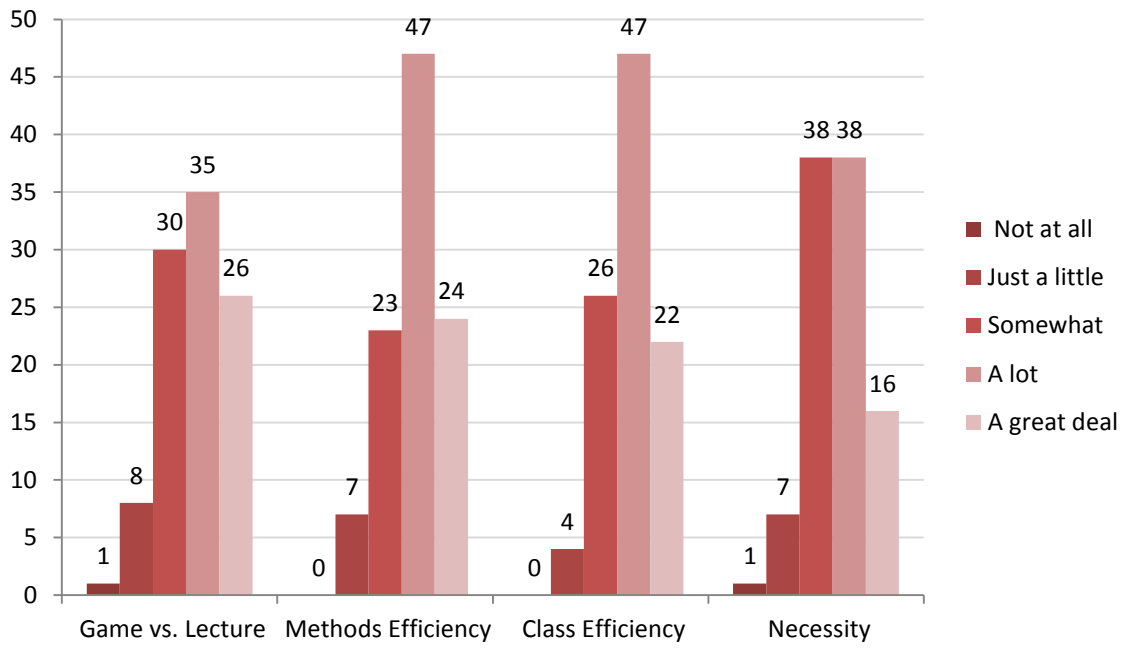

Figure 7: Percentage distribution for Simulation Games' Pedagogical Potential

IV.CONCLUSION

This study indicated that from the viewpoint of the students, a virtual project-based simulation game has a great potential to be used as an efficient pedagogical tool in construction education. According to the participants' responses, most of them play computer games, albeit to different degrees. Over half of them are also used to playing computer games at least some time per day. Most players reported that they had no problem with the speed of the game Skyscraper Simulator whereas on average, they were dissatisfied with the graphical appearance of the game. Although most students stated that in their opinion, the game was simple, they believed that the reasons for which their decisions were considered wrong were vague. However, the students said that playing the game helped them imagine themselves working on a real construction site. They also believed that the game was efficient for learning the construction process. Most players thought that the game changed their perception of construction site. In addition, most of them reported that they substantially used instructions while playing. They agreed that the game put them in positions to make decisions as a project manager. They also believed that the game developed their analysis ability. Furthermore, most students stated that computer simulation games improve the efficiency of traditional pedagogical methods. Over half of them also said that the class efficiency could be enhanced to a great degree by using computer simulation games. Most students reported that they prefer learning by playing to listening to lectures. Most of them also believed in the necessity of experience through such games. In other words, according to the test results, the virtual project-based simulation game was both interesting and efficient from the viewpoint of the participants. The game helped the learners use their knowledge and practice their skills and abilities, thus developing them as a result.

Project-based simulation games virtually place students in construction sites where they can see the whole construction process in a relatively short time, thus providing them with construction experience. Such simulations help students test alternative strategies and observe the outcomes in risk-free environments. Additionally, realistic tasks mirrored in project-based simulation games provide students with skills applied in real world positions. Therefore, such games should be pursued in construction education.

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