

# Strengths & Weaknesses of a Project-Based Simulation Game as an Educational Tool

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## ABSTRACT

This research study was conducted to investigate the potential of a virtual project-based simulation game for being used as an educational tool, from the viewpoint of construction students. For this purpose, 135 undergraduate construction students played Skyscraper Simulator, which is a virtual project-based simulation game focused on construction management. After playing, the students completed a questionnaire to share their opinions on the game's strengths and weaknesses. For assessing their responses, the comments were categorized by means of the constant comparative method of qualitative analysis and were counted for each category. The results indicate that the participants believed that Skyscraper Simulator has the potential to help substantially with comprehension of main concepts in construction management, and so it has positive effect on educating undergraduate construction students.

**Keywords:** Construction, Education, Project-based, Simulation, Strength, Weakness

## I. INTRODUCTION

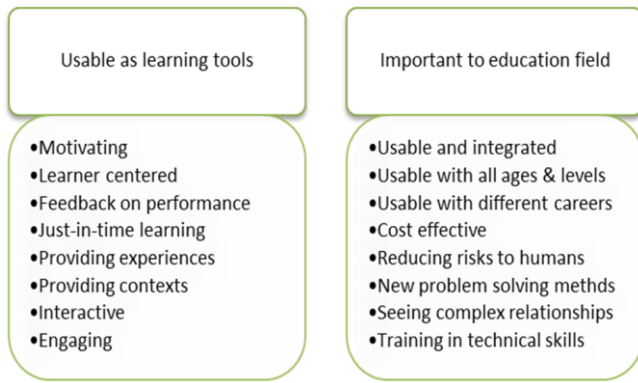
During recent years, game-based learning has attracted much attention (Bodnar et al. 2016). Some features of games make them useful as learning tools (Fig.1) (Pariafsai 2016a). Moreover, games have positive effects on conceptual understanding, problem solving, and critical thinking (Dabbagh et al. 2016). Educational games increase both motivation and engagement of students (POSSA 2011). Furthermore, game-based education can also improve students' attitudes in undergraduate engineering classrooms (Bodnar et al. 2016).

Recently, using educational simulations has increased substantially (Kincaid et al. 2001). Fig. 1 indicates why they are important to the field of education (Pariafsai 2016a, Kincaid et al. 2003). By visualizing situations encountered on the job (Hale Feinstein, Mann, and Corsun 2002), simulations develop the awareness of real world issues and understanding of course subjects (Philpot et al. 2005, Crown 2001, Hirose, Sugiura, and Shimomoto 2004). Accordingly, students can understand

construction projects and plans much better (Messner et al. 2003). Simulations expose students to realistic experiences without any risk (Nikolić 2011).

Simulation games can develop professional skills of construction students, thus having the potential to be used as practical learning tools (Agapiou 2006, Scott, Mawdesley, and Al-Jibouri 2004). Some simulations have developed for teaching construction processes thus far (Nikolic, Jaruhar, and Messner 2011). In addition, researchers have proven that project-based methods can be used as an alternative educational model in academic environments (Baş 2011).

In order to exploit the most efficient methods in construction education, the potential of new educational models should be assessed. Having this aim in mind, this research was conducted to assess the viewpoint of undergraduate construction students on both strengths and weaknesses of a virtual project-based simulation game in construction education.



**Figure 1:** Features of simulations (pariafsai 2016e)

## II. METHODS AND MATERIAL

This study aimed to investigate strengths and weaknesses of a project-based simulation game in construction education from construction students' perspective. Skyscraper Simulator was selected for this purpose since it includes main subject areas typical for construction management curriculum (Pariafsai 2013). This virtual project-based simulation game directs players on the management of constructing skyscrapers. Players should manage and complete all activities and related sub-activities. They should buy needed equipment and hire required personnel. Both cost and duration of projects are affected by the players' decisions. The players can see the outcomes of their decisions since an indicator shows both spent time and remaining funds during the game. In addition, the gradual completion of projects can be seen throughout the game.

This research study was designed into two sections including playing the game and completing a survey. 135 undergraduate construction students took part in the test (Pariafsai 2016b). Every one managed to build a skyscraper completely (Fig. 2). Then, they filled out a questionnaire including questions about their age, gender, years of experience in construction, and whether they have passed any courses in construction management. The participants were also asked to share their opinions about the strengths and weaknesses of Skyscraper Simulator.

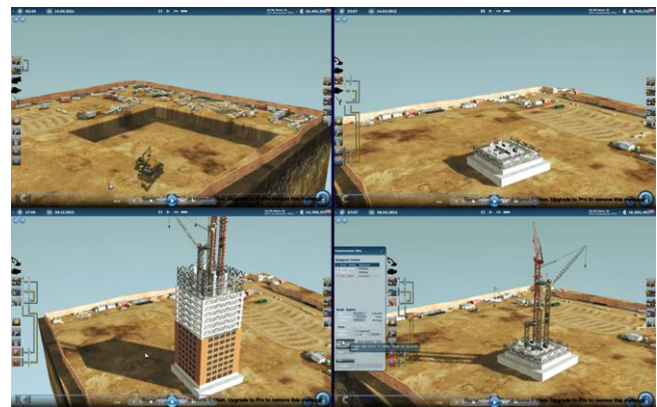
## III. RESULTS AND DISCUSSION

This study hypothesized that a project-based simulation game like Skyscraper Simulator has potential to be used as an effective learning tool in construction

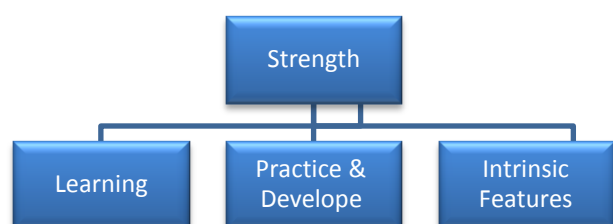
education. 135 undergraduate construction students including 66 females (48.9%) and 69 males (51.1%) partook in the test (Pariafsai 2016f). The mean construction experience of the students was less than 1 year ( $\mu = 0.789$ ,  $\sigma = 1.9326$ ) whereas 77% of them had no construction experience (Pariafsai 2016d). 68.1% of the participants had some knowledge in project management since they had passed relevant courses (Pariafsai 2016c). After playing, the students answered the hypothesis question, both strengths and weaknesses of the game as a learning tool in construction education. Their comments were analysed then for emerging categories using the constant comparative method of qualitative analysis (Lincoln and Guba 1985), and were tallied for each category.

### Strengths

127 out of 135 participants, i.e. 94% of them, gave their opinion on the strengths of the game. One of the 127 students stated that the game was useless from his perspective. Other ideas were categorized into three major groups including learning opportunity, practice and development chance, and intrinsic features of the game (Fig. 3). The three main groups were also classified in some subgroups in order to facilitate the ideas assessment.



**Figure 2 :** Different stages of constructing a skyscraper



**Figure 3:** Classifying the ideas in three major groups

### 1) Learning Opportunity:

The first main group of ideas, i.e. learning opportunity, was categorized into seven subgroups (Fig. 4). 26 students found the game helpful in learning about materials, machinery, structural interactivity between construction stages, architectural aspects which were not theoretically taught, and some details. One student stated that if modified, the game would be useful for learning. One of the players found learning through the game better than studying. The other mentioned that it helped her to learn more quickly. One participant commented that the game completely changed her perception of construction. In addition, one student believed that the game helped with learning since it showed real construction site conditions to some extent.

In addition, 6 students stated that the game made them learn about construction principles, foundation construction, and concrete casting. 23 players noted that by playing, they learned about the construction of a building from beginning to end. 27 participants stated that the game showed them construction stages. 16 players reported that the game helped them learn about construction management (Table 1).

Furthermore, 31 players believed that the game was useful for learning about construction site (Table 1). One of them emphasized that the game could help students without any experience in construction management or supervision and could provide them for working on real construction sites. The other said that the game gave her the chance to see a real construction site which could not be imagined by studying. Another one commented that the game made him more familiar with pieces of work done on a construction site. In addition, a student stated that the game makes him learn about construction site management. Other learner stated that the game could develop the ability to supervise a construction site.

30 students reported that the game taught them about construction machinery including their functionalities, their applications in each construction stage, and how to use them (Table 1). One of them stated that the game helped her learn about cooperation between construction vehicles. The other commented that the game made her find that machinery of the best quality should always be used in order to obtain the best results. In addition, three students stated that the game taught them how to manage machinery.



**Figure 4 :** Classification of the learning opportunity

Moreover, 7 learners reported that the game made them familiar with construction personnel including experts, engineers, constructors, and workers. As well, 8 participants thought the game help them learn how to manage the workforce (Table 1).

Further, 4 students said the game made them familiar with the costs (Table 1). One of them added that the game made her pay more attention to the remaining capital. 9 participants stated that the game helped them with learning about capital management (Table 1). One of them also mentioned that he learned how to increase funds by selling the vehicles which are not requisite anymore.

4 players commented that the game makes them pay more attention to the duration in which a building is constructed. Moreover, 4 participants commented that they learned scheduling better by playing (Table 1). One of them stated that she became familiar with the work sequence. She also added that she found out that wrong decisions increase the cost. Another student said she learned about the proportion of required time for one stage to that of the other. Further, 4 students stated that the game taught them how to manage the time while building (Table 1).

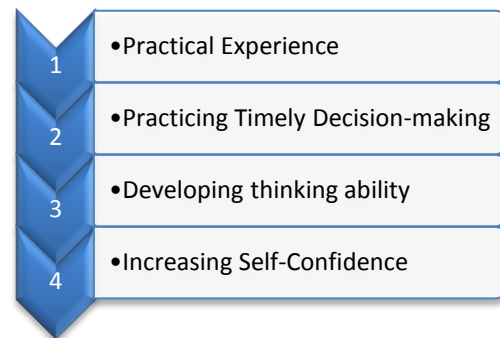
**Table 1:** Categories and Frequency of First Main Group

Chance of Learning	Frequency
Helpful in Learning	26
Learning about Basic Principles of Construction	6
Learning about Construction Process	23
Learning about Construction Stages	27
Learning about Construction Management	16
Learning about Construction Site	31
Learning about Construction Site Management	3
Learning about Machinery	30
Learning about Machinery Management	3
Learning about Construction Personnel	7
Learning about Personnel Management	8
Learning about Costs	4
Learning about Capital Management	9
Learning about Importance of Time	4
Learning about Scheduling	5
Learning about Time Management	4

## 2) Practice and Development:

The second main group of opinions, i.e. practice and development, was classified in four subgroups (Fig. 5). 5 participants cited practical experience as the game's strength. 3 ones of them stated that the game gives them the chance to practically experience what they had theoretically learned before (Table 2). One student said he could understand what he had learned during the previous years. 5 learners commented about getting experience for instance in construction, management, or control. Moreover, 5 players reported that they felt they were working on a real construction site while playing. To sum up, 15 students thought the game provide the opportunity for experience. 9 students thought the game provided the opportunity to practice timely decision-making (Table 2). Furthermore, two

students added that the game developed their thinking ability. Another one thought it could also encourage creativity. In addition, 5 players thought the game could increase self-confidence (Table 2).



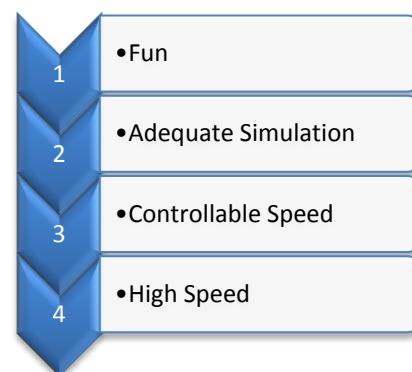
**Figure 5 :** Classification of practice & development

**Table 2:** Categories and Frequency of Second Main Group

Strength	Frequency
Practical Experience	15
Practicing Timely Decision-making	9
Developing thinking ability	3
Increasing Self-Confidence	5

## 3) Intrinsic Features:

The third main group of opinions, i.e. intrinsic features, was classified in four subgroups (Fig. 6). 14 players believed that playing the game was fun (Table 3). One of them commented that the game made him eager to work in the real world. Moreover, 8 students stated that the game adequately simulated construction (Table 3). Half of them believed that it simulated construction machinery completely. One added that the game helped him learn which materials and vehicles should be used in construction.



**Figure 6 :** Classifying intrinsic features in four subgroups



5 players stated that they could control the speed of the game. In addition, 3 participants cited the high speed as the game's strength (Table 3). However, one student complained that the game had to be stopped when assigning new workers in order to decrease the time period of construction whereas the game was slow in some other parts.

**Table 3:** Categories and Frequency of Third Main Group

Strength	Frequency
Fun	14
Adequate Simulation	8
Controllable Speed	5
High Speed	3

### Weaknesses

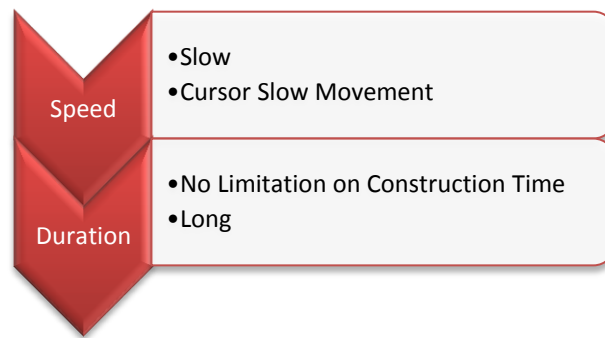
However a few skipped the opportunity to comment, 122 out of 135 participants, i.e. 90.4% of them, were very generous, open, and frank in their statements on the weaknesses of the game. 8 students stated that it was flawless in their opinion. Other ideas were categorized into three major groups including time aspect, quality, being inadequate for learning (Fig. 7). The three main groups were also classified in some subgroups in order to simplify the ideas investigation.



**Figure 7:** Classifying the ideas in three major groups

#### 1) Time Aspect:

The first main group of opinions, i.e. time aspect, was categorized into two subgroups (Fig. 8). 27 participants cited slowness as the game's weakness (Table 4). One of them complained that it wasted the time a lot. In addition to these 27 ones, one student commented that the game's speed was low in some parts and it was high in some other parts. 13 students cited the slow movement of the cursor as the game's weakness (Table 4). In addition, one participant complained that the cursor didn't move correctly.



**Figure 8:** Classifying time aspect in two subgroups

2 participants mentioned the time required to complete the project was not limited in the game (Table 4). Moreover, 3 students complained about the long time needed for completing a project. One of them believed that reducing the construction time would add much more attraction to the game.

**Table 4:** Categories and Frequency of First Main Group

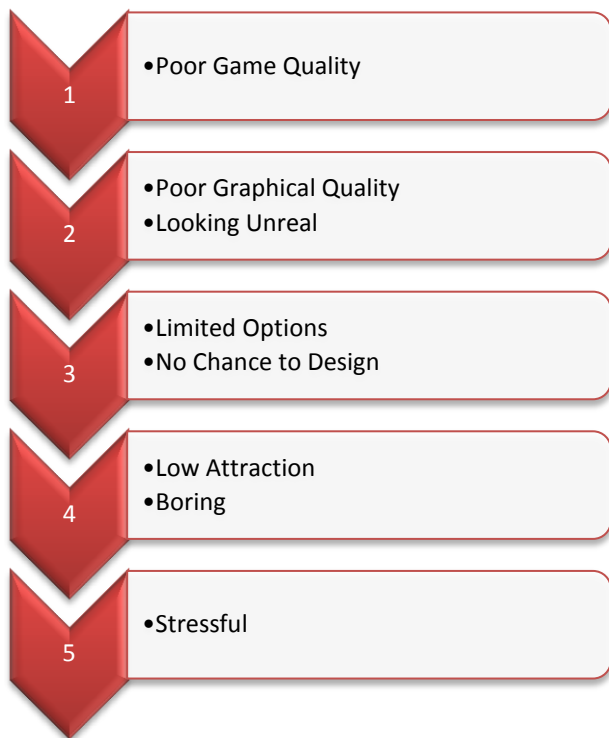
Weakness	Frequency
Slow	27
Cursor Slow Movement	13
No Limitation on Construction Time	2
Long	3

#### 2) Quality:

The second main group of opinions, quality, was categorized into five subgroups (Fig. 9). 9 players cited the poor quality as the game's weakness (Table 5). One of them complained that it was a superficial game adequate for students at ages between 15 and 19. The other one believed that the game was too simple for it didn't proceed to construction details. Furthermore, the graphical quality of the game was rated negatively by 49 participants (Table 5). Two students stated showing personnel could add realism and attraction to the game. One student said that details were not clear especially in the foundation stage. The other commented that he didn't completely understand how interior walls were erected or how ornament was made.

In addition, two participants commented on the poor quality of the game view. One of them remarked that some part of the game went out of the view while zooming. However, one student stated that the game provide the opportunity to watch the construction site form a bird's-eye view. Moreover, two students mentioned the game animations. One of them explained that at high speeds, vehicles collided, but

they continue working without any problem. He also complained of the poor graphical quality of the machinery. In addition, three students cited inappropriate proportion as the game weakness. One of them explained that the excavated area and the foundation dimensions were disproportional. He also stated that vehicles were out of proportion with the building. Two others stated that the items, for instance, the keys used for increasing/reducing the number of workers, were tiny. Finally, one student stated that the symbolic meaning of icons were vague in the game.



**Figure 9:** Classifying quality factor in five subgroups

6 participants complained that the game bore no relation to reality (Table 5). One of them commented that the project was built in such a high speed that seemed unreal. Another one believed it would look more believable if the workforce was shown in the game. The other participant stated that it would be better if construction stages were more precise to bear a close resemblance to reality.

Furthermore, 18 learners commented that limitation was one of the game’s weaknesses (Table 5). Five students complained about limited options in the game. Other student stated there was no option to rent a vehicle instead of buying it whereas sometimes it could be more economical to rent some construction machinery. Another participant complained that it was

not possible to buy four construction sites at the same time. He added that the game was closed without any warning if he tried to buy the fourth site. However, one participant said that the game gave players the chance to freely choose from a range of construction sites with different characteristics and prices. She added that in this way, the player could make the best decision while selecting the construction site. In addition, one student said that she could learn how to play only by watching while she preferred to be instructed by some explanation as well. Furthermore, five students stated that they preferred to be more involved while playing. One of them believed that it should have been possible to decide about building’s application, materials used for decoration, the type of windows, and so on. The other student thought it would be better if the game gave her the chance to design interior space and landscape.

2 students cited “no chance to design” as the game’s weakness (Table 5). One of them stated that there was no chance to design the tower as he preferred before constructing it. The other complained that the game provided no opportunity for neither interior nor landscape design.

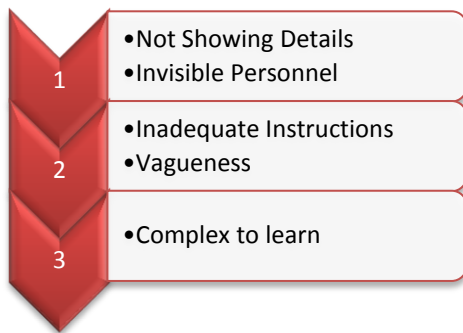
In addition, 4 participants cited the lack of attraction as the game’s weakness. One of them believed that if it was competitive it would be more attractive. 7 players complained that the game was boring. In the eyes of 6 learners, the game was stressful (Table 5). One of them stated that it caused her to feel she might not be able to pay the costs and complete the project on time in the future. Another one commented that when playing, she worried that the project might not be completed, the remaining money might be inadequate, or spending money on enhancing the efficiency might cause the lack of fund. Another student added that the game resulted in a feeling of failure.

**Table 5:** Categories and Frequency of Second Main Group

Weakness	Frequency
Poor Game Quality	9
Poor Graphical Quality	49
Looking Unreal	6
Limited Options	18
No Chance to Design	2
Low Attraction	4
Boring	7
Stressful	6

### 3) Being Inadequate for Learning:

The third main group of opinions was categorized into three subgroups (Fig. 10). 6 participants complained about the game's instructions. One of them stated that players could learn only by watching without any available explanation. She added that studying books and listening to lectures could improve both the speed and the quality of learning. The other student cited the incomplete instructions as the only weakness of the game. 2 players commented that they preferred to be instructed in Persian. In addition, one student believed that English instructions retarded the speed of his perception at the beginning of playing. Another one stated that without reading the instructions in Persian before playing, learning how to play the game would be complicated and time-consuming.



**Figure 10 :** Classifying the third main group

14 students complained that the game didn't pay enough attention to details. One of them believed that showing more details could help with learning much more. Another one said that it could make the game more believable. Additionally, one student stated that paying inadequate attention to details made the game too simple. Another one complained that construction details were inaccurate in the game. Finally, one other participant believed that instead of complete details, the game just gave superficial information about construction. He illustrated his opinion by giving an example. He commented that for instance, it was not clear how much materials were used in each stage.

10 participants complained about vagueness in the game. One of them commented that the owner, contractor, and constructor were not identified in the game. One student stated that the details in the foundation stage were unclear. The other one complained that he didn't understand how the interior walls and decorations were made in the game. Another

one stated that financial factors, including location, machinery, and workforce costs, were not tangible in the game.

Furthermore, 8 students complained about not showing the workforce. One of them believed that the game would look more acceptable if the workforce could be watched while playing. The other one commented that it could make the game more attractive.

3 students cited complexity as the game's weakness. One of them complained that at the beginning, he could slowly understand the actions since the game instructed players in English. Another one explained that because of his limited knowledge, the game was difficult for him at the beginning of playing. He added that learning the game would be difficult unless the players studied the instructions in Persian.

**Table 6:** Categories and Frequency of Third Main Group

Weakness	Frequency
Inadequate Instructions	6
Not Showing Details	14
Vagueness	10
Invisible Personnel	8
Complex to learn	3

## IV. CONCLUSION

The results of this study indicated that from the viewpoint of the students, a virtual project-based simulation game like Skyscraper Simulator has the potential to help significantly with understanding the main concepts in construction management. Comparing the frequency of different comments on the strengths of the simulation with each other reveals that the game was helpful in learning about construction site, machinery, construction stages, construction process, and construction management. In other words, the content and coverage of topics was generally praised, however lack of details was also used in some comments. It has also been useful for practicing experience, as well as being fun. On the other hand, the prevalence of complaints about the game indicates that the appearance of simulation was considered as its worst aspect. Moreover, a considerable number of players also complained about its low speed, limited options, not showing details, slow movement of the cursor in the game, and the vagueness there was while

playing. There were some aspects that the participants had mixed reviews. For instance, some deemed playing the game fun, while some others felt that it was boring. Nevertheless, the frequency of the comments on the strengths and weaknesses of the simulation shows the focus point of the students. As the customers of simulation games, students can provide very practical feedback to be used as a useful source for developing such games in construction education.

Project-based simulation games provide students with construction experience since they put players virtually in construction sites, thus showing them the whole construction process in a relatively short time. Therefore, such games allow players to observe the outcomes of using alternative strategies without any risk. Moreover, project-based simulation games mirror realistic tasks, thereby developing skills applied in real world positions. Accordingly, such simulations deserve consideration in construction education.

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