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Lessons learned From a Simulation Project in Construction Education

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Lessons Learned from a Simulation Project in Construction Education

Abstract

Virtual Interactive Construction Education (VICE) is a simulation designed for construction education. The purpose was to provide the traditional lecture-based construction contents along with supplementary instructions in a project-based learning environment. Six modules were proposed as a curriculum delivery guideline including: single span bridge, residential building, light commercial, heavy commercial, highway, and segmental bridge. The single span bridge was the first module used for prototype development providing an opportunity to design, analyze, implement, and test for effectiveness. This paper describes the design steps and results of this three-year research project. VICE-Bridge required participants to sequentially order the construction activities and then select the required resources for each activity such as personnel, equipment and material. The diversity of participants' responses were represented by an animation or real situation video within the simulation. Different iterations were tested during development and used for analysis, design changes and implementation using feedback from participants to augment development process. The hypothesis of this investigation is that simulations can have a positive effect the participants' interest in science, technology, engineering and mathematics (STEM) disciplines and particularly construction. In addition, the study investigated the participants' perceptions of simulation on learning and the contrast between project oriented delivery and simulations when compared with traditional teaching methods. VICE was tested three times during the development process by 99 participants that included both high school students and college students. High school students were selected as a sample for two reasons. First, their knowledge and preconceptions about construction would not be tainted as would a student body from a construction program. Secondly, it was important to know what effect the educational game might have on an entry level population. A mixed methodology of both quantitative and qualitative methods was used in this research. The results from the post-survey indicated whether VICE had an influence on participants' interest in each of the STEM disciplines. Participants also stated to what degree their performance in simulation was impacted by different factors, including prior knowledge from experience, prior knowledge from classroom instruction, instructions within the simulation, "ask a consultant" feature, instructional videos, and learning from mistakes. In addition, the participants' beliefs about using simulation-based learning and project-based learning methods as a part of integrated construction program curriculum were analyzed. Moreover, the weaknesses and strengths of VICE, asked as open-ended questions, were categorized and qualitatively analyzed for all participants. These various feedback data were further developed, then, utilized in subsequent iterations. Since the participants' population consisted of college and high school students, a comparison was used to show any possible difference in each group for aforementioned questions.

LITERATURE REVIEW

Harteveld (2012) defined game as "a voluntary activity which is governed by rules and that includes a clear goal and feedback about progression toward this goal" (pp. 8) and then states that a simulation game should have game-like features while it deals with real world concepts. Mayer (2009) believed the origin of political-military gaming efforts goes back to years before World War II by Japanese and German armed forces; then, the war gamin gradually transferred to a nonmilitary context. Many efforts have been taken place to use the simulations and games in classrooms to facilitate learning during late 1950s until early 1970s. These effort are rehabilitated with the emerge of new technology and computers (Balasubramanian & Wilson, 2006). There are numerous instances of using simulation for education during recent years. Mayer et al. (2013) developed an evaluation methodology for simulation and gamin that contains a framework, conceptual models, research designs, data gathering techniques and evaluation tools. They also believed that a suitable a pregame, an in-game and a postgame instrument can be design to measure the relevant variables. For example, a comparison between pre and postgame variables, with or without control group, can show the effect of simulation. According to Mayer et al. (2013), knowledge gained data, measured with knowledge tests, would be more robust when it is combined with a self-evaluation measurement.

Using simulation for construction is not new. Gantt chart, Critical Path Method (CPM), Graphical Evaluation and Review Technique (GERT), Program Evaluation and Review Technique (PERT), and Earned Value Management (EVM) are instances of efforts, which took place during 1920s to 1950s, to utilize simulations in construction management. However using construction simulations as an educational method in academia was not widely considered until 1990s in which a few studies by different researcher began to investigate the role of simulation and educational games in construction education (Rokooei & Goedert, 2015). In addition, some research projects were conducted in similar fields like project management or civil engineering that showed using simulation resulted in a better understanding and more enjoyed learning experience (Nikolić, 2011; Rokooei & Goedert & Fickle, 2015; Szot, 2013). However, simulations are becoming an effective instrument in construction education to expose students to realistic experiences without real costs or risks (Nikolić, 2011). Mitigating different risks of construction education, especially on-site ones, decreasing costs, repeatability of iniquitousness of training make simulations a very efficient and effective tool for construction education.

METHODOLOGY

In order to evaluate the main hypothesis, the project was designed in three sections: pre-quiz, main simulation, and post-survey.

Pre-Quiz

Participants first create a username and login to the application where they are directed to a series of questions. These questions are similar to the post-evaluation questions presented within the main simulation. The data, gathered from this section, create a baseline for construction content knowledge before exposure to the simulation. Students are allowed three attempts to answer each question. In addition, students can choose the "I do not know" option; therefore, each data field has four possible situations.

Main Simulation

After finishing the pre-quiz section, students play the main simulation. The first page of the main simulation is a set of demographic questions, and then students are directed to the main page of VICE (Figure 1).

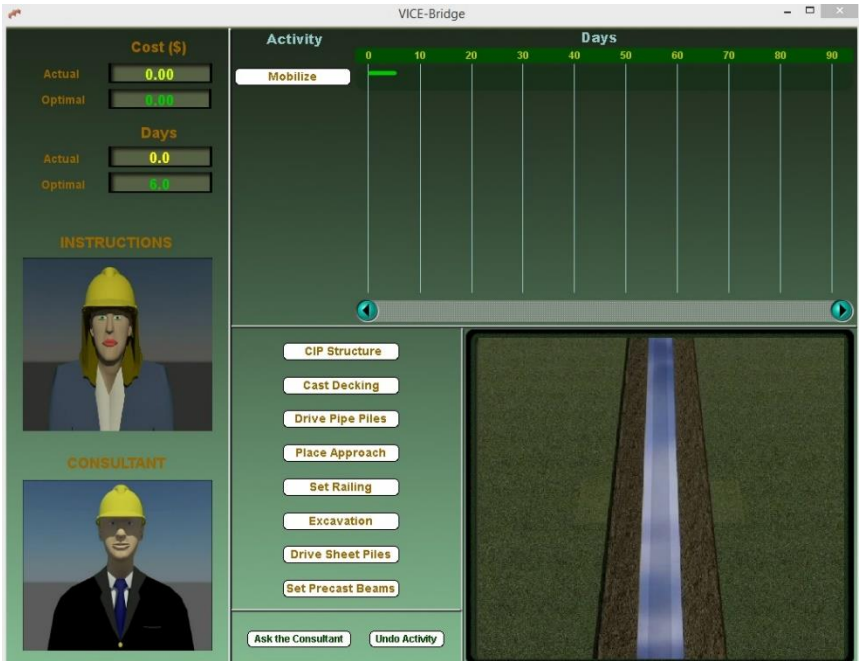

Figure1: Main page of VICE

The first activity of the VICE simulation is WBS sequencing. Students select the correct order of main activities of a single span bridge project. A player shows an animation corresponding to each activity after each selection; thus, students can see the gradual completion of the project. Choosing a wrong activity will result in an error message and an animation of catastrophic result of the selected activity. In this case students need to correct their selection by asking a consultant, which increases the cost of the project. Having completed the WBS stage, students go through each activity and complete the sub-activities required. The main tasks that for participants is to determining the amount of equipment, personnel and material for each activity. Resource selection is an iterative process whereby the program allows a range of values

and methods. Selections outside of this range results in a call from the project manager requesting another look. Options within the range have cost and schedule ramifications. They also fill purchase orders based on their calculations. Each activity begins with an educational module and then provides the information needed for making decisions. Educational modules contain real videos, audios, animations, pictures, and charts that describe a process, calculation or activity. Providing information and instruction in educational modules and then asking similar, albeit more complicated questions without the aid of the education module allows the students to scaffold their learning. A cost and duration indicator will show the consequence of each decision students make throughout the simulation. Students can compare the actual cost and duration with optimum cost and duration and therefore see the degree they have deviated from the optimum decisions.

Post-Survey

Students are automatically directed to an online survey after completion of the main simulation. They answer a set of questions and rate their perception of parameters before and after intervention for different construction subjects including construction process, materials and equipment methods, estimating, planning and scheduling, cost analysis and control, and safety on a five-point Likert scale.

RESULTS

Ninety-nine students, including 73 high school and 26 college students, participated in the test during 2013-2014. Seventy three percent had no previous experience with virtual learning. While previous publications (Goedert et al., 2012; Goedert et al., 2013 a & b; Rokooei et al., 2014) showed the effectiveness of VICE using the actual performance of VICE participants, this paper uses a self-reported survey's data to present the effects of VICE on participants' perceptions.

Construction and STEM Interest Increase

Participants in both groups were asked to rate whether their interest increased after playing the simulation. A five-point Likert scale provided the following options: totally disagree, disagree, neutral, agree, and totally agree. As shown in Figures 2a & 2b, the difference between two groups is more apparent in construction than STEM fields. Only 29% of high school students stated that they totally agree or agree that their interests increased after playing VICE (3% + 26% respectively) whereas 81% of college students reported that their interests increased after playing VICE.

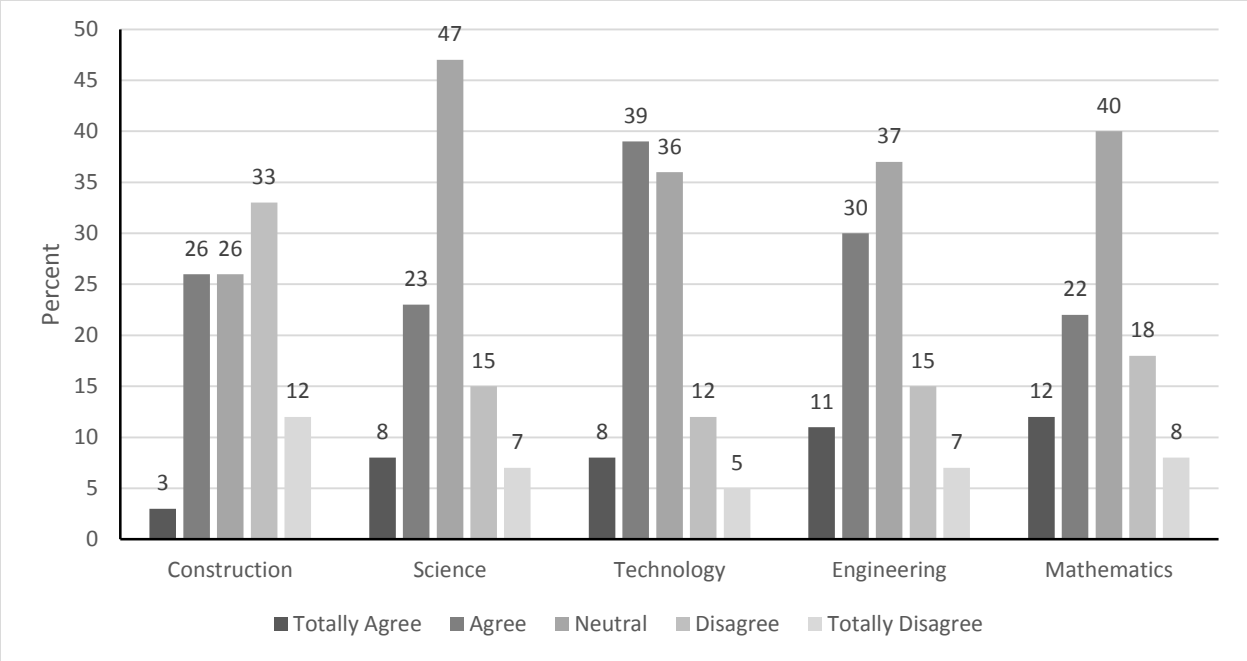

Figure 2a: Percentage of Likert scale options in construction and STEM for high school students

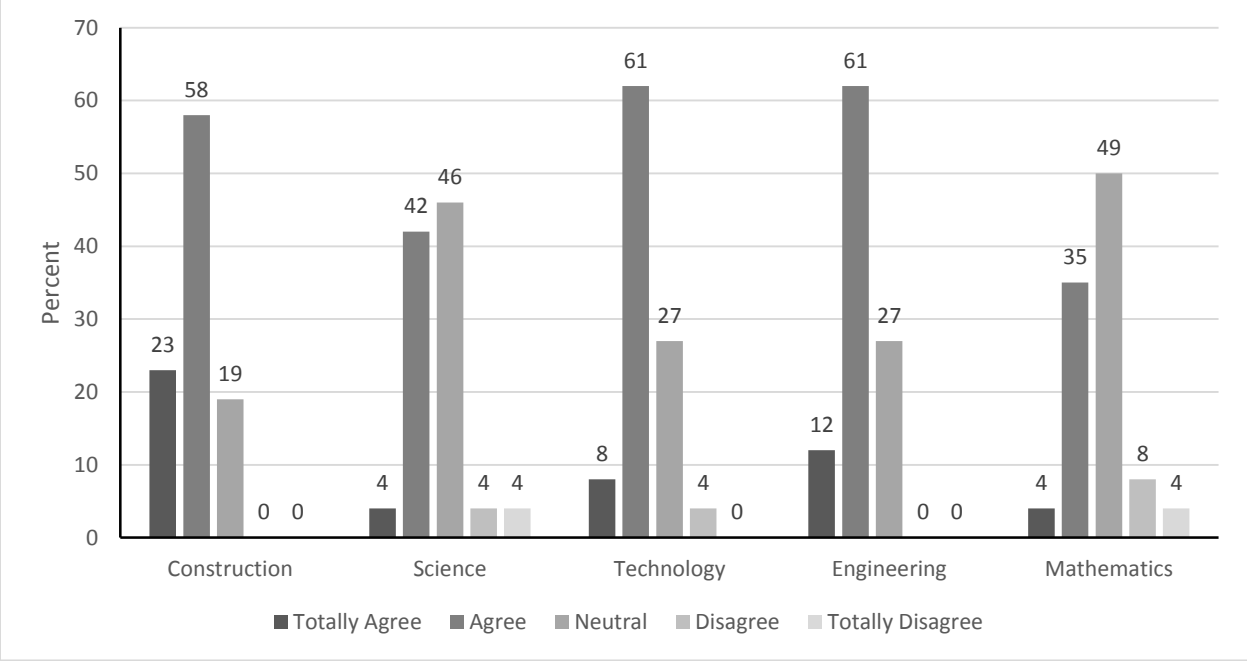

Figure 2b: Percentage of Likert scale options in construction and STEM for college students

Source of Performance Impacting

Ziv, Ben-David and Ziv (2005) believe that a unique approach to making and learning from mistakes is the main characteristic of simulation-based education and can be considered as

a powerful educational experience and an effective tool for improvement. Participants were also asked to rate the impact of each item, including prior knowledge from experience, prior knowledge from classroom, instructions within the simulation, "ask a consultant" feature, educational modules, and learning from mistakes, on their performance. As shown in Tables 1a and 1b, the “learning from my mistake” option is mentioned as the main factor that affected the participants’ performance.

Table 1a: Source of performance impacting high school students (%)

	Prior knowledge from experience	Prior knowledge from classroom	Instructions within the simulation	"Ask a Consultant" feature	Educational modules	Learning from my mistakes
Excellent help (%)	0	0	4	7	7	35
Much help (%)	4	5	36	29	23	35
Some help (%)	21	25	32	31	34	15
A little help (%)	26	25	22	24	25	14
No help (%)	49	45	6	10	11	1
Sum (%)	100	100	100	100	100	100

Table 1b: Source of performance impacting college students (%)

	Prior knowledge from experience	Prior knowledge from classroom	Instructions within the simulation	"Ask a Consultant" feature	Educational modules	Learning from my mistakes
Excellent help (%)	4	4	4	4	12	32
Much help (%)	23	31	31	48	50	48
Some help (%)	38	54	58	24	35	20
A little help (%)	12	12	8	12	0	0
No help (%)	23	0	0	12	4	0
Sum (%)	100	100	100	100	100	100

Using Simulation for Learning Real World Construction Concepts

Participants also were asked if they thought that simulations like VICE would help in learning real world construction management concepts and strategies. As shown in Table 2, 40% of all participants believed that simulations have excellent or much help in learning real world construction management contents while 23% of them did not think that simulation can help too much. The percentage of each of five Likert scale levels for both high school and college students is also shown in Table 2.

Table 2: Using simulation for learning real world construction concepts (%)

	High School Students	College Students	All Participants
Excellent help (%)	1	0	1
Much help (%)	34	56	39
Some help (%)	36	36	36
A little help (%)	26	8	21
No help (%)	3	0	2
Sum (%)	100	100	100

Simulation versus Traditional Lectures

In another section, participants were asked to rate whether they believed 1-project-based learning method and 2-simulations like VICE are more effective learning tools than traditional lectures. As shown in Tables 3a & b, both college students, who had previous knowledge about construction, and high school students found project-based learning methods and simulations more effective than traditional lectures. However, college students had a higher level of agreement.

Table 3a: Project-based learning and simulation vs. traditional lectures – High School Students (%)

	1-Project-oriented delivery is a more effective learning tool than traditional subject based delivery.	2- Simulations are more effective learning tools than traditional lectures.
Totally Agree (%)	11	4
Agree (%)	41	36
Neutral (%)	36	43
Disagree (%)	8	7
Totally Disagree (%)	4	10
Sum (%)	100	100

Table 3b: Project-based learning and simulation vs. traditional lectures – College Students (%)

	1-Project-oriented delivery is a more effective learning tool than traditional subject based delivery.	2- Simulations are more effective learning tools than traditional lectures.
Totally Agree (%)	8	4
Agree (%)	57	49
Neutral (%)	35	35
Disagree (%)	0	12
Totally Disagree (%)	0	0
Sum (%)	100	100

Integration of Simulation and Project-Based Learning with Construction Curriculum

Furthermore, the participants were asked whether they believed that project-based learning and simulation should be integrated throughout the construction program curriculum. Again, college students were more positive about integrating project-based learning and simulation with construction program curriculum. For example, 81% of college students were "Totally Agree" or "Agree" with integration of simulation with construction curriculum whereas only 43% of high school students had a similar opinion. The percentage of each level for each question is shown in Tables 4a & b.

Table 4a: Integration of project-based learning and simulation with construction curriculum – High School Students (%)

	1-Project-based learning should be integrated throughout the construction program curriculum	2- Simulations-based learning should be integrated throughout the construction program curriculum
Totally Agree (%)	21	11
Agree (%)	50	32
Neutral (%)	26	45
Disagree (%)	3	7
Totally Disagree (%)	0	5
Sum (%)	100	100

Table 4b: Integration of project-based learning and simulation with construction curriculum – College Students

	1-Project-based learning should be integrated throughout the construction program curriculum	2- Simulations-based learning should be integrated throughout the construction program curriculum
Totally Agree (%)	23	8
Agree (%)	58	73
Neutral (%)	19	19
Disagree (%)	0	0
Totally Disagree (%)	0	0
Sum (%)	100	100

Open-ended Feedback

Participants were also asked to share their opinions about the strengths and weaknesses of VICE. This feedback from each test session was a useful source for each iteration of VICE development. Students, as the customers of simulations, were able to provide very practical feedback to be used as much as possible in the next development phases. Comparing the feedback of high school students with college students' reveals that the former group considered the appearance of simulation as the most important aspect whereas the college students paid more attention to the content of simulation. For example, one of the most prevalent complaints

stated by high school students was the length of simulation. “It’s too looooong”, “Took a long time, started to get boring”, “Too video heavy” are examples of weaknesses mentioned by high school students. On the other hand, the comments from college students show they were mostly involved with decisions they had to make. “Information and formulas not present when asked to solve problem…”, “Entering in the calculations”, and “When a wrong answer was entered, there was no explanation on why the answer was wrong or how to fix the problem” are instances show the focus point of college students. Moreover, a few high school students mentioned graphics as a negative point of VICE, while none of the college students had a similar complaint, and they mostly had a positive perspective toward the visualization and graphics of VICE.

CONCLUSION

The findings of this paper endorse the results of previous VICE-related publications. It is shown that simulation and educational games can have positive effect on participants’ perception. They can provide students with construction experience by virtually putting them in a 3-D workplace environment. There are a few instances of simulation available for construction education, and it seems simulations can be used as supplementary tools in construction education. Participants in both high school and college students groups also stated that their interest in construction, science, technology, engineering and mathematics had improved, albeit to differing degrees. In addition, participants indicated that simulation and project-based learning are effective alternatives along with the traditional lecture-based method and can be a part of construction curricula. Generalizing the results beyond the investigation of this specific educational game would not be appropriate. However, the results indicate that further investigation is warranted particularly toward increasing interest in the STEM disciplines. Further investigations could include additional discipline specific simulations tested with participants from a broader socio-demographic and educational background.

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