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Investigating Students' Perception Using Construction Management Simulations

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Today, construction programs are incorporating a wide variety of active learning methods in their curricula to improve student learning outcomes and induce a more knowledge retention rate. Simulations and educational games are one of the fast growing and effective active learning methods that have been implemented in many programs. However, there are few instances of such learning methods applied in construction programs and a limited number of research projects have been conducted to investigate short-term and long-term outcomes of these methods and applications. This paper presents construction students' perceptions of tested simulations with regards to the features, knowledge gained, level interest, and important aspects of simulations in integrating simulations in construction program curricula. Two construction management simulation applications were designed, developed, and tested with students with limited or no previous construction knowledge at University of Nebraska-Lincoln. Based on Dale's Cone of Learning instructional model, this study aims to investigate the same sample group's perception regarding their experience with simulations after a two-year intervention, when they were juniors or seniors. Construction engineering and management students were selected for this study and a self-evaluation survey was utilized to determine their perceived knowledge and identify the effectiveness of the method. Results indicate the students' responses in various areas have similar patterns in their corresponding areas right after playing the simulations.

Keywords: Simulation, Educational games, Construction education, Dale's Cone of Learning,

Background

Simulation in Education

Simulations emerged in education in the late 1950s. However, the growth lasted a decade and did not show an increasing trend (Harper, Squires, & Mcdougall, 2000). The advent of new technological tools in multimedia with new featured graphical software provided a platform to use contemporary learning ideas in education. Processes that are long (e.g. population growth) or short (e.g. force analysis in 3-D environments) are considered as suitable subjects for simulation (Harper, Squires, & Mcdougall, 2000). In addition to time, other important factors for choosing simulated environments in education included cost, level of task difficulty, and risk. Although the use of simulation for education encompasses a broad range of fields, the frequency of simulation application and related research is used more in high-risk fields such as aviation and medical science. Hahn (2010) argues that one advantage of using simulation rather than other media is its ability to increase either the transfer of required skills or the efficiency with which transfer is gained after conducting a thorough review of the history of simulation in aviation. In a study on the utility of simulation in medical education, Okuda et al. (2009) investigated the role of simulation as an educational tool and reported on the use of simulation in basic science, physical examination, clinical clerkships, and skills training at the undergraduate level; and anesthesiology, surgery, obstetrics, emergency medicine, pediatrics, and critical care at the graduate level of medical education. Although, aviation and medical science are the most frequent users of simulations other fields have also taken advantage of simulation. Wolfe and Bruton (1994) reviewed the history of business gaming and summarized how “management gaming” evolved to its current state. In a study of simulation in international relations education, Starkey and Blake (2001) reviewed the history of simulation in politics. According to their report, simulations can be utilized as tools to support decision-making processes at situational points, help policy makers realize the outcomes of various states, and assist students in the comprehension of international systems and real-world problems. Wolfe and Bruton (1994) reviewed different computerized entrepreneurship simulations considering playing aspects and environments and suggested activities to cover the majority of subjects discussed in an entrepreneurship course. Künzel and Hämmer (2006) used a simulation successfully in a research project in a psychology course and report a high acceptance of the simulation by groups of psychology students.

Simulation in Construction Project Management

Although there are various opportunities that can be brought to construction management education through the support of simulation, it is not yet widespread among construction departments and hence, the huge gap between construction management education and simulated learning methods should be filled by developing relevant applications. Program Evaluation and Review Technique (PERT) and similar scheduling tools are good examples of construction simulations that have been used for over 50 years (Rokooei & Goedert, 2015). However, until recently construction simulations have made little progress. Martin (2000) developed Contract & Construct, a simulation in which five strategies—including quality, morale, time, cost, and balance—were selected for use in teaching an MBA course. Davidovitch, Parush and Shtub (2006) developed a Project Management Trainer (PMT) simulator in which they investigated the role of keeping and reviewing learning history on project management education. They found that using the history mechanism, along with the undo ability, is an effective tool to improve the learning process. A multi-agent framework for situational simulations was later developed by Rojas and Makherjee (2005 and 2006) for general purpose construction. MERIT, developed by Wall and Ahmed (2008), included a blended learning approach. Collofello (2000) implemented a software project management simulator in which lifecycle model comparison, risk management, software inspections, critical path scheduling, and overall planning and tracking were the main objectives of the simulation. The Virtual Construction Simulator 3 was a three-dimensional interactive model for creating and reviewing schedules, which showed simulations are perceived as more interesting than traditional teaching methods. The research findings indicated that using simulation resulted in an increase in participants’ knowledge in the efficient management of the construction process and resources (Nikolić, 2011). Szot (2013) utilized SimProject, developed by Jeffrey Pinto and Diane Parente at Pennsylvania State University as a project management simulation and concluded that participants’ perceptions of project management knowledge and their confidence in using knowledge gained increased after the completion of the simulation. Overall, there are three common characteristics among the studies using simulation for project management education: 1) simulations are introduced as supplementary material for project management courses, 2) PMBOK standard is not used in developing simulation, and 3) self-assessment has been the main method for evaluation of simulation effectiveness.

Experiential Learning

Prior studies have investigated to track and measure students' learning improvement. Two prominent taxonomies that are currently referred to in education to describe learning process, knowledge, problem solving, and critical thinking are Bloom's taxonomy (Bloom et al., 1956) and Edgar Dale's Cone of Learning (Dale, 1963). Bloom's taxonomy was defined to explain the development of cognitive intellectual skills so that proficiency at lower levels is necessary to reach to higher levels. Six levels of Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation represent the levels from low to high, respectively. Each level is associated with a variety of verbs or actions performed by a student proficient at that level. Moving from lower levels to higher ones demands more active learning. The second model is Edgar Dale's Cone of Learning which depicts different levels associated with intensity of involvement in learning. As shown in Figure 1, lower levels represent more active learning and result in higher knowledge retention. Dale's Cone of Learning has been used as the core concept of many research projects for measuring student performance and retention of knowledge. Krain (2010) used case studies and problem-based learning as active learning method in international relations classrooms to evaluate student engagement and showed active learning methods enhanced students' perceptions of the exercises' effectiveness. Rahn and Moraga (2007) investigated the effect of complex performance assessments with multiple embedded tasks and concluded that performance assessment task covering a subset of content resulted in increased learning in a senior/graduate level engineering decision theory class. Chung (2011) proposed an approach that enables student to learn more by authoring eBooks through a systematic methodology using a case study. Davis and Summers (2014) studied how Dale's Cone of Learning can be utilized to positively impact student learning in a foundational leadership course at Purdue University and stated successful achievement of course effective learning by applying lower levels (active learning) strategies.

Figure 1: Cone of Learning (Adapted from Edgar Dale, *Audio-Visual Methods in Teaching*. Holt, Rinehart, and Winston, 1963)

Methodology

The main objective of this study is to investigate the effects of active learning on students' perception. It is shown that integrating experimental learning (active learning) and traditional methods can achieve better educational results in academia. The core concept of this study is designed based on the Dale's Cone of Learning that proposes higher retention rate for learning by doing. Simulation applications are a part of active learning that have been illustrated to be effective and engaging. Two simulation applications are designed, developed, and tested in the Durham School of Architectural Engineering and Construction at the University of Nebraska-Lincoln between the academic year of 2013-2014. These two simulation applications were project-based pedagogical models that utilized construction management concepts to enhance the quality of education and empower construction students. These applications transformed traditional subject-based lectures of construction management in construction programs to project-based, virtual, interactive simulations. The main objective for using construction simulation applications was to investigate if the addition of a simulation is effective in learning construction management contents and engaging students in learning process.

Target population for this research are students with no or limited previous construction knowledge. Simulation effectiveness and engagement is evaluated through perceived knowledge gained and measuring actual performance. A retrospective pre- and post-evaluation, which is a commonly accepted tool for measuring the effectiveness in educational experiments is used to investigate students' perception. In addition, measuring actual performance of students is performed by a knowledge content pre- and post-test. Results of different analyses in both applications showed a statistically significant difference between pre- and post-situations, which illustrated the effectiveness of simulations in educating construction contents. Preliminary findings of these studies have been disseminated through various publications (Rokooei, et al., 2014 & 2015; Goedert et al., 2016). The findings indicated that simulation application can be efficiently used for construction education as rich supplementary tools. In continuation of previous research, a study was designed to investigate if students can remember precisely what they learned and experienced in simulation sessions after a long period. The research question is designed as "to what degree can students recall what they have experienced with simulations after a long intervention?" A survey is prepared to research on following:

- What features of simulation can students remember from the application they played?
- To what do extent students think their interest in STEM (Science, Technology, Engineering, and Math) areas and construction had increased as a result of playing simulation?
- What sources do students think impacted their performance while playing simulation?
- How well do students think simulation applications can help in learning real-world construction concepts and strategies?
- What aspects of simulation applications do students think are important and should be emphasized?

Target population for this survey were junior or senior students who played either of those two applications between 2013-2014. A five-point level scale was used to quantify the responses and data were gathered and coded using multinomial distributions.

Results

Twenty-nine students participated in this study in Spring and Fall of 2016. Of the total participants, 79% were senior students and 41% had no previous experience with any other simulation before the tested applications. Students were asked to indicate what features of simulations they can recall. Among the features including Duration, Results, Procedure, Graphics and Contents, Duration had highest average while Result was rated as the least feature. Participant were asked to rate their perceived knowledge before and after playing simulation using a 5-level Likert scale in four subject areas of 1: Project Integration Management, 2: Activity Management, 3: Resource Estimation, and 4: Developing Schedule. A related samples Wilcoxon signed rank test at a significance level of 0.05 was used to determine if a significant difference exists between the means of each pair in four areas. As shown in Table 1, there was a statistically significant difference between pre-and post-situations in all four areas.

Table 1
Related Samples Wilcoxon Signed Rank Test for 4 Subject Areas

	Area1-Pre	Area1-Post	Area2-Pre	Area2-Post	Area3-Pre	Area3-Post	Area4-Pre	Area4-Post
Average	2.48	2.93	2.34	3.03	2.41	2.83	2.31	2.79
St. Dev.	0.83	0.88	0.81	1.12	0.95	0.97	0.81	0.86
Related Samples Wilcoxon Signed Rank Test	0.003		0.001		0.001		0.002	

Participants were also asked to rate if they believe their interest had increased after playing the simulation in six areas. As shown in Table 2, Construction and Project Management had highest average weight. The results of this table were consistent with the corresponding table derived from self-evaluation survey.

Table 2
Positive Effect of VICE on Participants' Interest

	Construction	Project Management	Science	Technology	Engineering	Math
Strongly Disagree (%)	0	0	3	0	0	0
Disagree (%)	7	14	14	10	10	10
Neutral (%)	41	31	52	52	49	69
Agree (%)	49	52	31	38	41	21
Strongly Agree (%)	3	3	0	0	0	0
Average	3.48	3.45	3.1	3.28	3.31	3.1
Standard Deviation	0.69	0.78	0.77	0.65	0.66	0.56

Participant were also asked to specify the impact of different sources on their performance while playing simulation. Possible sources, and the percentage of each agreement level are shown in Figure 2.

"Learning from mistakes while playing" was rated as the most important factor. This was also consistent with previous results, emphasizing this unique feature of simulation compared with other educational tools.

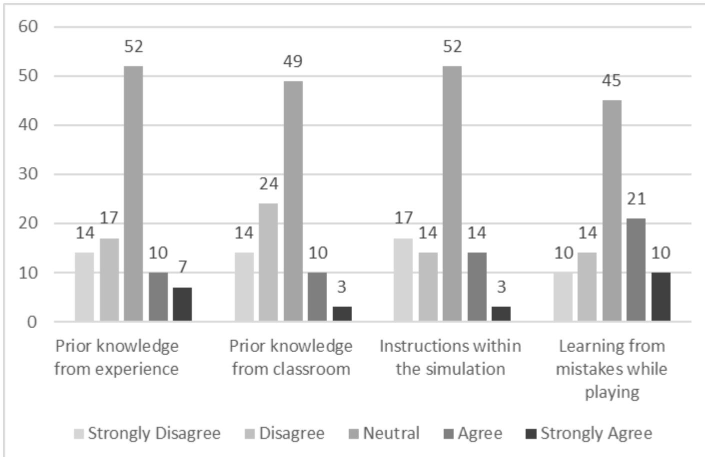

Figure 2: Percentages of Sources of Impact

Students were asked to express their opinion whether they think simulation applications can help in learning real-world construction concepts and strategies. The average rate of this item was 3.31 (out of 5) which shows their relative agreement. In addition, they demonstrated their agreement levels about these two statements:

a) *I find simulation instruction to be a more effective learning tool than traditional lectures.*
b) *I believe simulation-based learning should be integrated throughout the construction program curricula.*

Table 3 shows the percentage of each agreement level. Both statements indicated above average agreement. The result was also consistent with what they previously stated on use of simulation in construction programs.

Table 3
Students' Opinions about Using Simulation in Construction Programs

	Statement a	Statement b
Strongly Disagree (%)	3	7
Disagree (%)	10	3
Neutral (%)	48	41
Agree (%)	31	38
Strongly Agree (%)	7	10
Average	3.28	3.41
Standard Deviation	0.88	0.98

Moreover, participants were asked to rate the importance of various features in construction simulations. These features included 1: Possibility of playing several times (repeatability), 2: Possibility of playing at any desired time, 3: Needing limited amount of time to finish, 4 Ability of seeing the outcome of a decision, 5: Learning through graphics and 3D views of a construction project, 6: Being in an isolated environment and learning individually, 7: Learning through computers instead of being in class, and 8: Ability to see application of construction theories and contents in a simulated problem. These features (i.e. F1 to F8) are stated with corresponding percentage of each agreement level in Table 4.

Table 4
Students' Agreement about Different Features of Simulation

Features	F1	F2	F3	F4	F5	F6	F7	F8
Strongly Disagree (%)	7	10	7	7	10	14	14	14
Disagree (%)	17	7	10	7	10	10	10	7
Neutral (%)	52	42	55	45	39	38	42	45
Agree (%)	24	38	28	34	38	38	34	31
Strongly Agree (%)	0	3	0	7	3	0	0	3
Average	2.93	3.17	3.03	3.28	3.14	3	2.97	3.03
Standard Deviation	0.84	1	0.82	0.96	1.03	1.04	1.02	1.05

As shown in Table 4, ability of seeing the outcome of a decision and flexibility of learning time have been rated as the main features of simulation.

Conclusion & Discussion

Presently, new educational advancements are being encompassed by construction departments. Integrated curriculum, engage learning, experimental learning, and active learning are instances of new approaches. Simulation and educational games are rich tools that can be effectively incorporated in construction programs. Although construction has a lag in embracing simulation applications in its curriculum compared to other educational fields, a few developed construction simulations have shown their effectiveness and engagements. According to Dale Cone of Learning, active learning methods such as simulations can have higher rate of retention. This study aimed to show determine the perception of students to active learning method through simulation and how Cone of Learning model can be applied in construction programs. Preliminary results of this study show simulation applications can be effective and increase the retention by converting passive learning methods to active ones. However, generalization of the results is limited because of the number of students who participated in the survey. Lack of control group is another limitation in this study, although it is a prevalent issue in educational experiments. In addition, there is no standardized method for assessment. To justify the finding of this study, designing more simulation applications, focusing different construction topics, and more longitudinal experiments will be considered as extension of this study.

References

Bloom, B., Englehart, M., Furst, E., Hill, W., & Krathwohl, D. (1956). *Taxonomy of educational objectives: The classification of educational goals. Handbook I: Cognitive domain.* New York: Longmans, Green.

Chung, C. (2011). LBA: Learning By Authoring, a new pedagogy in learning. ARISE-TM, (pp. 1-5).

Collofello, J. S. (2000, 11). University/Industry Collaboration in Developing A Simulation-Based Software Project Management Training Course IEEE Transactions on Education, vol. 43, no. 4,. IEEE Transactions on Education, 43(4), 389-393. doi:10.1109/13.883347

Davidovitch, L., Parush, A., & Shtub, A. (2006). Simulation-based Learning in Engineering Education: Performance and Transfer in Learning Project Management. Journal of Engineering Education, 289-299.

Davis, B., & Summers, M. (2014). Applying Dale's Cone of Experience to increase learning and retention: A study of student learning in a foundational leadership course. Engineering Leaders Conference 2014 Retrieved from http://dx.doi.org/10.5339/qproc.2015.elc2014.6

Goedert, J., Rokooei, S. (2016). Project-Based Construction Engineering Education in a Virtual Environment, International Journal of Construction Education and Research, 12(3): 208-223, DOI: 10.1080/15578771.2015.1121936

Hahn, S. (2010). Transfer of Training from Simulations in Civilian and Military Workforces: Perspectives from the Current Body of Literature. Retrieved from www.adlnet.org.

Harper, B., Squires, D., & Mcdougall, A. (2000). Constructivist Simulations: A New Design Paradigm. Journal of Educational Multimedia and Hypermedia, 9(2), 115-130.

Harteveld, C. (2012). Making Sense of Virtual Risks: A Quasi-Experimental Investigation Into Game-Based Training. Amsterdam: IOS Press.

Kirkpatrick, D. L., & Kirkpatrick, J. D. (2006). Evaluating Training Programs: The Four Levels. Oakland: Berrett-Koehler Publishers.

Krain, M. (2010). The Effects of Different Types of Case Learning on Student Engagement. International Studies Perspectives, 11, 291–308.

Künzel, J., & Hämmer, V. (2006). Simulation in University Education:The Artificial Agent PSI as a Teaching Tool. SIMULATION, 82(11), 761-768. doi:10.1177/0037549706075251

Martin, A. (2000, 6). A simulation engine for custom project management education. International Journal of Project Management, 18(3), 201-213. doi:10.1016/S0263-7863(99)00014-9

Nikolić, D. (2011, 8). Evaluating a Simulation Game in Construction Engineering Education: The Virtual Construction Simulator 3. Dissertation. PA, USA: The Pennsylvania State University.

Okuda, Y., Bryson, E., DeMaria, S., Jacobson, L., Quinones, J., Shen, B., & Levine, A. (2009). The utility of simulation in medical education: what is the evidence? Mount Sinai Journal of Medicine , 76(4), 330-43.

Rahn, R., & Moraga, R. (2007). The study of knowledge retention and increased learning through the use of performance based tasks. Retrieved from http://www.niu.edu/CEET/p20/scholarship/vol2/B13F.pdf

Rokooei, S., & Goedert, J. (2015). Lessons learned From a Simulation Project in Construction Education. 122nd ASEE Annual Conference and Exposition. Seattle, Washington: American Society for Engineering Education. doi:10.18260/p.24420

Rokooei, S., Goedert, J., Weerakoon, A. (2014). Simulation as an Effective Tool for Gender Education in Construction, 6th Conference on Higher Education Pedagogy, Virginia Tech, Blacksburg.

Starkey, B. A., & Blake, E. L. (2001). Simulation in International Relations Education. Simulation & Gaming, 32(4), 537-551. doi:10.1177/104687810103200409
Szot, J. M. (2013, 3). The value and effectiveness of project management simulation as a capstone activity in an executive MBA educational program. A thesis submitted for the degree of Doctor of Philosophy in Strategy, Programme & Project Management. Lille, France: Skema Business School.
Wall, J., & Ahmed, V. (2008). Use of a simulation game in delivering blended lifelong learning in the construction industry – Opportunities and challenges. Computers & Education, 50(4), 1383-1393.
Wolfe, J., & Bruton, G. (1994). On the use of computerized simulations for entrepreneurship education. Simulation and Gaming, 25(3), 402 - 415. doi:10.1177/1046878194253007