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Proceedings of the International Conference on Computing in Civil and Building Engineering
W Tizani (Editor)

The virtual construction simulator - development of an educational simulation game

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Keywords: simulation game, construction scheduling, education

Understanding the dynamic nature of the construction process and the ability to make important decisions about resource utilization, sequencing, site layout, and project-related risks are critical skills for design and construction engineering students. The increase in projects complexity and shorter schedules pose pressure to develop more efficient construction methods, and also many challenges to educators to prepare students to manage these multifaceted processes. One of the challenges construction engineering students frequently encounter lies in understanding the relationships and variability underlying complex construction processes.

To address some of these challenges, a small but growing amount of research has shifted toward exploring the value of educational simulations to allow students to experience construction issues in environments that closely resemble real construction project situations (Park and Meier 2007; Sawhney et al. 2000). Educational simulations are seen as learning environments that can complement traditional teaching methods and further enrich the learning experience. Several recent studies explore *situational simulations* as an opportunity to develop an authentic learning environment in which students can explore "what if" scenarios and practice strategic decision making skills related to construction processes. Internet-based Construction Management Learning System (ICMLS) is conceived as a discrete event simulation to allow students to test strategies related to construction materials, methods, scheduling, estimating, cost, and resource allocation (Sawhney et al. 2000). Virtual Coach is another example currently being developed as a temporally dynamic environment with system-generating random events requiring participants to quickly make appropriate decisions (Mukherjee et al. 2005). Since actual construction projects are characterized by constant changes, resource fluctuations, and unexpected delays, these simulations, although not yet fully implemented, aim to teach students the variability of some of these processes and equip them with skills to react to changes and modify strategies accordingly.

Research at the Pennsylvania State University initiated in 2004 focused on developing a construction schedule simulation application - the Virtual Construction Simulator - as a 4D learning module to visually immerse students in a 3D model allowing them to interactively create a sequence for constructing a building project. Two versions of the Virtual Construction Simulator (VCS) were developed and implemented in an upper level construction management course in 2006 and 2007 respectively, and demonstrated benefits in teaching construction scheduling (Jaruhar 2007; Wang 2007). Nonetheless, the existing VCS application lacks specific project-based constraints that would motivate consideration of the most feasible construction sequence. The feedback on the schedule solution exclusively comes from the instructor, limiting the students' exploration of various decisions consequences.

The current development effort is to leverage the research in educational simulations and extend the functionality of the existing VCS application into a more comprehensive simulation game with project constraints, rules, variability and system feedback. In this experiential simulation environment students will be able to make decisions about construction methods; daily resource needs; construction sequence; learn to manage various tradeoffs in controlling project duration, cost, quality and safety; and observe the impact of these decisions over time. Students have traditionally had very little understanding and awareness of workers' productivity fluctuation during construction or factors that cause changes or schedule delays, and therefore tend to adopt schedules as a determined sequence of activities with fixed durations. The VCS 3D aims to demonstrate to students the difference between the as-planned and as-built schedule resulting from the impact of factors such as weather, congestion, learning curve, or overtime based on construction project conditions. From the development perspective, the calculation of the as-built schedule is approached from a system dynamics model.

Currently, the VCS 3D simulation game is in the final development stage. Following the completion and preliminary testing, the VCS 3D will be implemented within a third-year construction engineering and management course. To determine the level of learning that occurred as well as the level of motivation during the activity, pre and post-test questionnaires will be administered, while focus groups will serve to assess any additional information about the interaction with the simulation, as well as the learning process that may not be otherwise captured though surveys and questionnaires.

Simulations and games have been largely stated to be advantageous and beneficial as instructional tools, however, their wide acceptance in educational curriculums has not yet happened due to the lack of convincing data. The reason for such state is because the direct measurement of the effectiveness of games and simulations has proven to be rather difficult. The ongoing research demonstrates the need for a complementary approach to traditional ways of teaching complex construction processes. The VCS 3D simulation game aims to address challenges in teaching students the dynamic nature of construction through active learning where students would practice decision making skills and explore consequences through trial and error in various situations, building confidence in handling similar situations in real life projects.

Acknowledgements

The authors thank the National Science Foundation (Grant 0935040) for support of this project. Any opinions, findings, conclusions, or recommendations expressed in this paper are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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