Design Issues and Implementation Strategies for Game and Simulation-Based Learning in Construction Education

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The idea of using games and simulations for construction education is not new. More recently, with advanced information and communication technology, games and simulations have been adopted as a part of undergraduate courses in construction education to serve as powerful hands-on tools for teaching practical and technical skills. Some research shows that games and simulations can increase interest, motivation, and retention, while improving cognitive abilities. However, the effects of games and simulations in learning and cognition depend on a variety of factors such as underlying models, information representation schemes, complexity levels, and implementation strategies among others. This paper focuses on design issues and implementation strategies for game and simulation-based learning. It also argues that the success or failure of games and simulations as educational tools significantly depends on the efforts performed to integrate them with other pedagogical activities. Finally, this paper proposes pedagogical schemes to appropriately apply games and simulations in construction engineering and management education.

Key Words: Games and Simulations, Construction Education, Instructional Design, Educational Technology

Introduction

In the traditional classroom, students are considered passive vessels into which instructors should transfer their knowledge on the basis of lecturing. Such a teaching method still dominates today's classroom. However, it has limited effectiveness in helping students develop high-level of thinking skills like applying learned knowledge to real situations (Gardiner 1994). Thelen (1995) argues that there is a disconnection between the "abstract and reflective mind" and the material world in which the body is situated. During the last decade, educational researchers have emphasized the necessity of harnessing the power of games and simulations to cope with this duality in education and training.

In the field of instructional design, there has been a shift from the instructivist towards the constructivist approach (Van Merriënboer 1997). Unlike instructivist learning theory, constructivists argue that knowledge is not transmitted to learners but constructed through activities or interactions within the learning context. Aldrich (2005) states that successful learning opportunities can be created when following this constructivist theory. Game and simulation learning is based on the constructivist theory where "trial and error" is a primary source of knowledge acquisition.

Education and training institutions must prepare innovative approaches for today's students who have grown up with digital technology and video games. These digital natives could be fundamentally different from previous generations in that they prefer learning actively by doing with technology rather than learning passively. Games and simulations can greatly enhance motivation and increase learners' active engagement and participation in learning. For this reason, games and simulations should be designed for educational purposes and be implemented by strategies for changing instructional practice to take full advantage of games and simulations in construction education. However, innovation in the classroom is not all about using technology tools.

Marton et al. (1997) describe that students as active learners show the deep approach to learning by seeking a personal and meaningful understanding of that learning. However, it is challenging for instructors to develop well-designed instruction based on meaningful integration of games and simulations into the classroom. In this context, this paper explores design issues for game and simulation-based instructions. Moreover, several implementation strategies for games and simulations in the classroom are suggested. The main purpose of this paper is to propose a guideline to instructors when implementing games and simulations as teaching tools in their classrooms. Games and simulations can be incorporated into the learning process to support the acquisition of new knowledge and skills.

Games and Simulations in Construction Education

Traditional classroom curriculum in construction engineering and management education may not provide the opportunity for practical experience to allow fledgling construction managers to explore the problems they may encounter in the real world (McCabe et al. 2000, AbouRizk and Sawhne 1994). To cope with this limitation, a number of games and simulations have been proposed for construction education.

The earliest approach to games and simulations as an educational tool in construction is the "Construction Management Game" (Au et al. 1969) which simulates the bidding process in the construction industry. This model has inspired a variety of research efforts in the area of games and simulations: CONSTRUCTO (Halpin and Woodhead 1970), AROUSAL (Ndekugri and Lansley 1992), SuperBid (AbouRizk 1992), Parade of Trades (Choo and Tommelein 1999), Simphony (Hajjar and AbouRizk 1999), STRATEGY (McCabe et al. 2000), The Construction Marketing Game (Bichot 2001), VIRCON (Jaafari et al. 2001), ER (Nassar 2002), and the Virtual Coach (Rojas and Mukherjee 2005). These efforts provide stepping-stones towards creating interactive, participatory, and contextually rich educational environments in construction engineering and management. Thus, using games and simulations to help students learn is not a completely new idea in the construction engineering and management education.

Construction can be described as a highly complex system which has a wide spectrum of interrelated elements with multiple feedback loops and non-linear relationships. It is extremely difficult to summarize the entire construction process very precisely. However, some key concepts in the construction process can be summarized for the educational purpose. For instance, through games and simulations, students can experience the changes of productivity depending on different construction methods, discover the difference among construction methods, and understand the importance of choosing appropriate construction methods. System dynamics can be used to capture interdependencies between diverse elements, trace changes of behavior of the complex system over time, and understand causal impact of the changes (Sterman 1992). Thus, the understanding of system dynamics is essential in designing more realistic and complex educational experience to support an integrated view of construction.

The traditional construction education model based on precise, well-defined problems and formal definitions may lessen the opportunities for the decision-makers of tomorrow to explore real-world problems. In the field of construction engineering and management, where context-specific knowledge and awareness is imperative, experiential learning can support contextual learning and thereby improve students' understanding of the concepts and their interrelations. In order to take full advantage of experiential learning in construction education, it is necessary to expose learners to realistic situations. The challenge then is to create real-world contexts in an interdisciplinary environment and examples in which students work through real-like problems. Games and simulations can be considered effective tools for achieving these goals when following appropriate pedagogical schemes.

Design Issues for Game and Simulation-Based Learning

Game and simulation-based learning happens through repeating cycles within the given context. It allows learners to elicit desirable behaviors as a result of interactions and feedback on their game plays. The main purpose of games and simulations should be edutainment so that the learner can be involved into intrinsic learning. In this context, games and simulations use intrinsic motivation. When serious games and simulations are incorporated into learning

activities in construction education, the learner can be easily engaged into learning and will voluntarily solve problems. For instance, in case that game characters have a certain problem and can only proceed further after solving the problem, students are motivated to provide a solution to continue the game.

There might be different opinions on designing games and simulations for learning based on the characteristics of game. However, literature review shows that there are several essential issues:

- Learning objectives and goals should be appropriate and clearly stated.
- Learning contents should be well prepared and organized for the learning objectives and goals.
- The scope of learning contents should be different based on the degree of difficulty.
- A set of broad experiences and practice opportunities should be provide for students to reinforce their knowledge from the various perspectives.
- Either knowledge discovery or knowledge applicability should be focused specifically.
- The proper cognitive level should be considered for each student. Learning activities should challenge students to work at a somewhat higher cognitive level by providing game and simulation exercise to encourage intellectual growth. In other words, designing game and simulation experience at a lower cognitive level than that of the students may create boredom, while designing experiences at a significantly higher level may create frustration.
- The delivery style and content should be properly adaptable to student reactions.
- The practice opportunities of both individual and team-based learning should be included with equal value. Individual analysis and reflection develops their own critical thinking and collaborative learning builds on coordination, leadership, partnership, and patience, thereby improving their social skills.
- Students should be encouraged to build up any background knowledge through textbooks, case studies, or discussions to choose a solution or make a decision on game and simulation strategies.
- Students should continuously monitor and diagnose their performance and capabilities on games and simulations through scoring or feedback.

Considering the intrinsic characteristic of construction as mentioned before, construction educators can take advantage of games and simulations to provide practical skills training, reinforce rarely used but important skills, and build up teamwork which is required for the construction industry. Due to these facts, it should be considered to provide experiential learning through games and simulations. Therefore, students are able to exercise required skills and also experience both undesirable and desirable outcomes resulting from their decisions about problems in the real-like scenario.

Implementation Strategies for Game and Simulation-Based Learning

The success or failure of games and simulations as educational tools significantly depends on the efforts performed to integrate them with other pedagogical activities. The following sections describe activities that instructors can use before, during, and after applying games and simulations.

Pre-Simulation Activities

Pre-simulation activities may involve a series of actions to assess the level of learner's prior knowledge and skills, clarify any theoretical background involved in the game or simulation, and provide preliminary teaching for students to participate in the game or simulation. Pre-simulation activities may also include surveys or quizzes, homework or practice with a set of exercise scenarios, and pre-simulation briefings. These pre-simulation activities enable students to prepare the basic knowledge or skills necessary for the tasks to be performed in the game and simulation-based learning environment and to fully understand what must be known before embarking on a game or simulation, such as a general project description, specific project objectives, background information related to either team or individual work. In addition, it is recommended for instructors to provide a specific method of evaluation and criteria for grading.

The specific pre-simulation activities to be performed are dictated by the learning objectives of the game or simulation experience. Proper learning objectives are paramount not only for an effective learning system, but also for effective assessment (Feisel and Rosa 2005). There are several dimensions that should be addressed, including learning styles, approaches to learning, orientation to studying, and varying levels of intellectual development (Felder and Brent 2005). In addition, the following issues should be carefully considered before applying games and simulations:

- Knowledge Applicability vs. Knowledge Discovery: If knowledge applicability is the focus, then a series of pre-simulation activities, such as lectures, reading assignments, and knowledge assessment evaluations, should be incorporated into the design of the experience. On the contrary, if knowledge discovery is the focus, then plenty of time should be allocated in the experience for significant post-simulation activities, as discussed later in this paper.
- Cognitive Levels of Activities: Catalano and Catalano (1999) explore the transformation of teacher-centered to student-centered engineering education. One of their recommendations is to design activities at the proper cognitive level. Surveys or quizzes could be used to assess the cognitive level of students before selecting a particular game or simulation exercise.
- Individual Work vs. Team-based Activities: Individual and team-based work are equally valuable in construction engineering and management education. Individual learning can be reinforced by providing students with opportunities to practice their own critical thinking skills. And, team-learning environments can provide an opportunity for students to develop team building and interpersonal skills. Role playing is an excellent example of a team-based activity that may be supported by games and simulations. For a role playing game, instructors should provide each role player with a set of rules, detailed instructions, a user's manual, and any other ancillary materials necessary for playing the role.
- Psychological Safety and Freedom: Klukken et al. (1997) argue that an environment where students are constantly guarding against any mistakes discourages creativity. The attitude of an instructor towards student mistakes may enhance or hinder psychological safety and freedom in a game or simulation. "Learning from mistakes" is the attitude that should be reflected in effective educational games and simulations. Thus, instructors should remind students that learning from mistakes is a valid pedagogical approach.

Simulation Activities

In simulation-based learning environments, learners are responsible for their own learning. Therefore, the role of instructor is radically different from the one in a traditional classroom environment. If a game or simulation is designed to be played by individual learners, instructors should supervise individual works and provide help, support, and encouragement to individuals when required. The role of instructors becomes that of a coach. On the contrary, if a game or a simulation is designed team-based learning, then the role of instructors should be that of organizers of the game or simulation or facilitators of the learner's learning experience.

The instructor has responsibility for conveying games and simulations as serious pedagogical activities to students since such activities demand students' focus and concentration. Furthermore, it is important to express to students that the results of games and simulations are not indicators of their level of achievement as they are exploring alternative actions and learning from the use of "what if" scenarios. Therefore, instructors should avoid assessing learning effectiveness immediately after games or simulations and before applying post-simulation activities.

Post-Simulation Activities

Post-simulation activities address two general purposes. One is to examine the dynamics of games or simulations exercises and the overall results. The other purpose is to reinforce the process of knowledge acquisition as well as the realism of the performance feedback. Therefore, post-simulation activities are essential to fulfill the educational value of games and simulations. Post-simulation activities can include post-simulation surveys, post-simulation debriefings, and group discussions. As a result of these activities, it may also be necessary for the instructor to carry out follow-up teaching.

In order to fully realize learning effectiveness, a post-simulation survey may be administered to each individual learner immediately after the game or simulation. This survey asks general and specific questions. General questions are usually centered in student perceptions of exercises. Specific questions tend to require learners to think analytically about their decisions and their consequences.

Evaluation and reflection are important steps for experiential learning. Instructors can take advantage of group analyses and debriefing sessions. In these activities, learners describe the events that occurred, account for their actions, and discuss the merits of alternative strategies to solve the problems encountered. These post-simulation activities may generate a cognitive conflict within a group of learners because students may challenge the perceptions and decisions made by others during the game or simulation. As a result of this cognitive conflict, learners begin to reorganize their ways of thinking about a particular set of events and how various perspectives contribute to a more complex understanding of the processes and projects they will work on throughout their career.

In evaluating the pedagogical effectiveness of games and simulations, blinded control studies can be employed, including an experimental group and a control group. One approach can be to assemble a panel of experts from the local construction industry to serve as judges. The decision-making skills of each subject can be evaluated through the introduction of a hypothetical situation in the same topical area as the game or simulation. The evaluation criteria developed by Russo and Schoemaker (1989) can be adopted. These researchers described the following ten major barriers to successful decision-making:

- Not taking enough time to analyze the problem.
- Solving the wrong problem.
- Not looking at all sides of the problem.
- Being overconfident while predicting outcomes.
- Relying on easily available data.
- Not using a systematic procedure.
- Not managing the decision-process of a group.
- Failing to understand evidence from past outcomes.
- Failing to systematically record and track results.
- Not evaluating the decision-making process.

The hypothetical situation should provide students with plenty of opportunities to make poor decisions by not successfully negotiating the barriers listed above. Each member of the judging panel assigns a grade for each one of the parameters depending on how well students were able to look beyond these barriers. Statistical data can be gathered from these longitudinal studies, and comparisons among the experimental group and the control group can be performed. This can provide valuable knowledge about the efficacy of the game or simulation as a tool to improve the decision-making process of current and future construction managers.

Finally, this process may evaluate the effectiveness of the game and simulation rather than the performance of the student. Therefore, it is not desirable to use the results of these evaluations as part of student grades.

Conclusion

The traditional construction education model based on well-defined problems and definitions may not be able to satisfactorily accomplish its mission of educating today's learners. Context-specific knowledge and awareness leads to improve students' understanding of concepts and their interrelations. Traditional education settings provide students with less opportunity for active participation and engagement due to the fears of failure. Therefore, learners need to be exposed to real-like situations in a safe place to practice skills. Games and simulations as safe learning environments, in which all actions and comments can be welcomed and analyzed under understanding that participation is the most important and problems or projects have the potential for multiple solutions, may be constructive to a participatory setting. Students can learn from mistakes and thereby gain a deeper understanding of the learning objective than a learner who avoids mistakes by chance without understanding concepts. In addition, games and simulations make it possible that instructors can offer students problem solving exercises where concepts are embedded in the context promoting learning within the nexus of the activity. This paper has emphasized that the

success of games and simulations as educational tools depends on the efforts performed to integrate them with other pedagogical activities. In order to enhance the effectiveness of such tools, this paper has also described activities that instructors can use before, during, and after applying games and simulations.

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