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SIMULATION BASED CONSTRUCTION MANAGEMENT LEARNING SYSTEM

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ABSTRACT

Incorporation into construction engineering and management curricula of tasks that improve the abilities of students to manage the complex dynamics, pressures, and demands of construction sites is becoming critical to meet the demands of the construction industry. These goals are, however, difficult to incorporate using traditional educational tools. This paper reviews the role, in construction engineering and management education, of computing and information technology in general and of simulation in particular. The paper provides an overview of a Simulation Based Interactive Construction Management Learning System currently being developed at Western Michigan University (WMU) as part of a three-year project funded by the National Science Foundation and Western Michigan University.

1 INTRODUCTION AND BACKGROUND

Preparing students for the challenges of managing large construction projects is an important responsibility and a difficult task (Tatum 1987). The instruction methods used in majority of construction engineering and management curricula rely, for the most part, on traditional methods such as exposing students to applied science courses. These traditional teaching methods, however, are often not fully capable of providing students with all the skills necessary to solve the real world problems encountered in construction (AbouRizk and Sawhney 1994) or conveying complex engineering knowledge effectively. Also, curricula often convey knowledge in fragments in a series of courses (Fruchter 1996 and Fruchter 1997).

Ideally, visits to construction sites or site training would constantly complement the more conventional classroom instructional tools. However, there are various complicating issues that make it impossible to rely on the sites. Foremost, the instructor cannot control the availability of a project at the necessary stage of completion. Also, visits of larger groups to construction sites may not be welcome, involve risk, and are unpractical (Echeverry 1996). Finally, the high cost of site training is a further impediment to its extensive use for construction education (AbouRizk 1993, AbouRizk and Sawhney 1994). Computing and information technologies in general and simulation in particular have the potential to act as excellent tools to complement construction engineering and management education.

2 CHALLENGES ADDRESSED BY THE RESEARCH

The challenges of education/instruction are manifold and range from issues related to the enhancement of the learning abilities of students to curricula integration and the inclusion in the curricula of hands-on, real-world experiences. The following paragraphs describe some of these challenges as well as some potential solutions to shortcomings.

- The improvement of the learning abilities of students: Generally, one of the most important findings of research efforts directed at identifying features that enhance student learning is that students learn more effectively and permanently when they can actively participate in the learning process (Chi et al. 1989). It is thus important to provide possibilities for the students to actively use and explore the new concepts as they learn them. Computing technologies such as course material on floppy disks or CD-ROM and the Internet can be helpful in complementing the instruction. Further, computerized (simulation) games that can respond to the user's actions allow for a learning experience to take place (AbouRizk and Sawhney 1994).

- Knowledge fragmentation: Current curricula do not give students a holistic view of their field of study. A

typical undergraduate program in civil engineering includes curricular components such as mathematics and basic sciences, humanities and social sciences, engineering sciences, civil engineering design, and civil engineering core courses (ABET 1993). Also, the conventional civil engineering curriculum, implemented at most U.S. universities, focuses on unlinked and independent core and support courses that convey knowledge in fragments. Often students neither retain nor are able to utilize knowledge acquired in previous courses (Bertz and Baker 1996). To address these shortcomings, there is the need to develop curricular instruments that will require students to pool their knowledge to solve authentic real-world problems. Project-based learning, where learning evolves around real-world projects that span various disciplines, can also be implemented to address these shortcomings.

- Providing hands-on experience: The incorporation of a practical element in construction engineering and management is of foremost importance. However, as discussed above, several factors complicate or even prevent the use of extensive site training. Computer-based games that simulate the environment of construction, with all its complex and dynamic relationships between different factors, can, however, bridge the gap between the classroom and the construction site by allowing the students to take actions and learn from the responses to these actions.

The research being conducted by the authors' will lead to the development of an integrated educational framework for the construction engineering and management program at Western Michigan University, which will be ultimately applicable to civil and construction engineering programs at other universities. Figure 1 shows the proposed integrated educational framework in relation to the civil and construction engineering program. The Interactive Learning System will be used as an instructional tool for the key courses identified in the figure to introduce practical construction management concepts. The proposed framework will address the challenges listed above.

While the Interactive Construction Management System integrates both the Internet and simulation, the projects and systems found in literature can generally be distinguished by their use of either the Internet or simulation. The following paragraphs briefly summarize recent developments in the area of application of Internet and simulation for construction engineering and management education.

Recently researchers have started exploring the instructional opportunities provided by the Internet. Fruchter and Krawinkler (1995), Fruchter (1996), and Fruchter (1997) describe the development, implementation, and testing of a new and innovative computer integrated Architecture Engineering Construction (AEC) course that takes a multi-site, cross-disciplinary, project- and team-oriented approach to instruction. Dymond (1996) portrays the use of WWW in undergraduate civil engineering education at the University of Wisconsin –Plattevile. A notable effect of the use of the WWW for instruction, the author mentions, is the increased enthusiasm of the students.

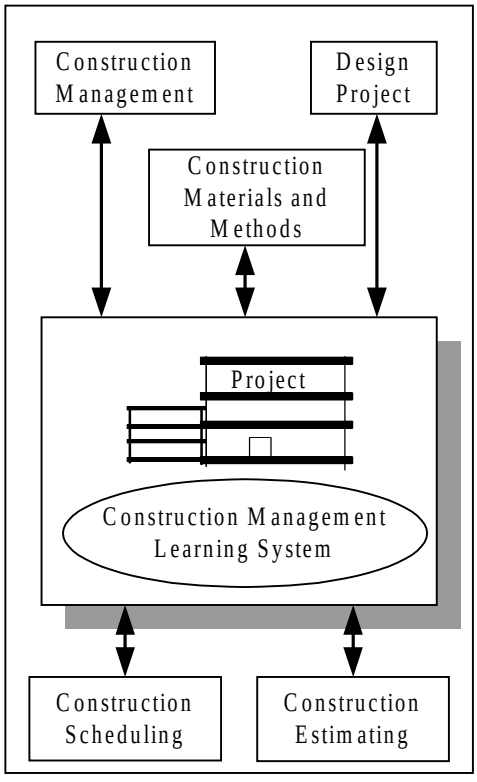

Figure 1: Proposed Integrated Educational Framework

Numerous examples of use of gaming and simulation to enhance construction engineering and management education exist in literature. The origin of construction games can be followed back to Au and Parti (1969) who suggested that computerized games involving economic, social, and technological decisions could be used for the education of engineers and planners. Halpin (1976) presented a model for the project gaming system CONSTRUCTO that generates close to real life game scenarios. These hypothetical projects can be planned, monitored, and controlled by the students. Harris and Evans (1977) developed a simulation game for the site managers in road construction. The game focuses on planning and controlling the construction of a stretch of pre-defined road. The required decisions involve resource and labor allocations. AbouRizk (1993) describes the development and implementation of a stochastic

construction bidding game for construction engineer training and for experimenting with various bidding strategies. Ferose et al. (1994) present the design, development, and implementation of two simulation-based computer-assisted instruction modules. The first illustrates the principles of fluid flow between two reservoirs, while the second simulates the typical tendering and project management situation. Samek and Landry (1997) describe the use of software packages, including simulation, to produce a series of models of simple but descriptive nature, to be used in entry-level courses or as review in follow-on courses to aid students in visualizing certain principles.

3 OVERVIEW OF THE CONSTRUCTION MANAGEMENT LEARNING SYSTEM

The Construction Management Learning System is an Internet based system that makes use of simulation and practitioner involvement to incorporate practical experiences in the construction and civil engineering curricula. The Interactive Learning System uses an interactive and adaptive learning environment to train students in the area of planning of construction processes. The system is process oriented and mimics the challenges faced by a construction manager on a real life project. It allows students to apply their knowledge of construction materials and methods, estimating, scheduling, resource allocation and utilization, fleet size determination, productivity and cost calculations, and decision making in relation to construction processes. Thus, with this system, adequate experience of the complexity of the dynamics of a construction site is provided to the students.

While the Interactive Construction Management System integrates both the Internet and simulation, the projects and systems found in the literature can generally be distinguished by their use of either the Internet or simulation.

Figure 2 provides the conceptual model of the Interactive Construction Management Learning System. The key features of the proposed Interactive Learning System are:

1. The system uses Internet as its launching medium. Students utilizing the World Wide Web (WWW) browser will be able to undertake interactive sessions of the learning system from remote locations. The internet-based approach will also result in effective dissemination of the system.

2. The system internally utilizes discrete event simulation, gaming, and stochastic methods to provide an interactive system that mimics the real construction processes.

3. It also utilizes multimedia databases to provide students with an interesting view of the selected construction processes and equipment.

4. Practical content relevant to construction processes and equipment is included in the system. Practitioner involvement clearly allows students to learn more about the construction management profession.

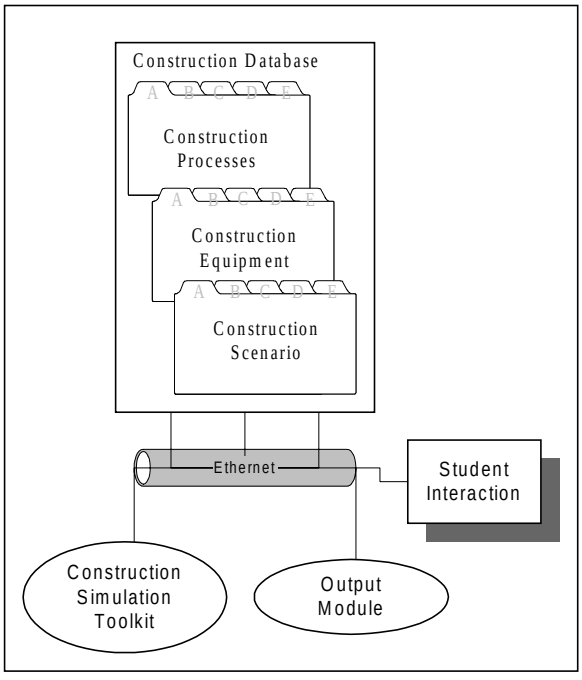

Figure 2: Conceptual Model

One of the key features of the Interactive Construction Management Learning System is the utilization of Internet as a launching medium. The authors' believe that this feature will allow successful utilization of the tool by construction and civil engineering students.

Figure 3 provides the implementation details for the system. The three main databases of the system are implemented as part of a single relational database management system (RDBMS) that complies with the object database connectivity (ODBC) protocol. The RDBMS is connected to the main program with the help of JAVA database connectivity (JDBC) to ODBC bridge drivers. The actual database features of the system are programmed using the JDBC Application Programming Interface (JDBC API) and JDBC manager. The construction simulation modeling toolkit and output module is programmed using the JAVA programming language—a programming language for developing Internet applications. The research team plans to utilize existing process interaction based discrete event simulation engine such as JavaSim (Buss and Stork, 1996), SimJava (McNab and Howell 1996), or JSIM (Nair et al. 1996). The

benefit of this approach is that these engines have been developed using JAVA programming language and as such can be directly linked to the main program, thus providing seamless integration. Web clients (students or users accessing the Interactive Learning System) will connect to the main JAVA based application through the hyper text transfer protocol (HTTP) over the internet by using standard WWW browser such as Microsoft Internet Explorer, Netscape Navigator, Mosaic, and HotMetal. The main program will process all transactions between the WWW clients and the Interactive Learning System.

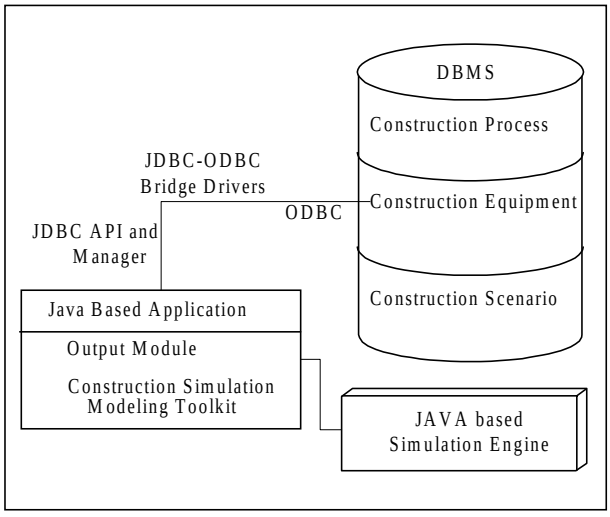

Figure 3: Implementation Plan

4 INTERNAL STRUCTURE

As can be seen from the above section, a few key features distinguish the Interactive Construction Management System from those described in the literature. These include the use of the Internet and simulation, a combination of active learning technologies and increased practitioner involvement. Interactive Construction Management Learning System is composed of the following components:

1. Construction Process Database: The repository contains a number of construction processes from residential, building, heavy engineering, and industrial construction. Visual as well as textual explanations of the processes are supplemented with multimedia elements.

2. Construction Equipment Database: This component contains information pertaining to equipment specifications, productivity, operation use, and manufacturer.

3. Construction Scenarios Database: A number of real-world scenarios are provided for the interactive simulation and gaming mode of the system. This database is linked to the Construction Process Database.

4. Construction Simulation Tool Kit: This element acts as a controlling module for the system. It provides support for the development of the simulation model during an interactive session, executes the simulation model and provides the result of the simulation study to the students (user).

5. Output Module: The module is used to provide the user with the response of the system.

5 UTILIZATION OF THE INTERACTIVE LEARNING SYSTEM

A critical factor in the success of the Interactive Learning System is the student interaction process. The system can be utilized in the construction materials and methods, construction estimating, construction scheduling, and construction project management courses. Additionally, the system will be utilized in other civil engineering courses, introductory pre-engineering courses and demonstrations to prospective transfer students. Figure 4 provides overview of the student interaction process. As seen in the figure the Interactive Construction Management Learning System permits the students to use it in three different modes:

1. Mode 1: Browse through the construction process database. This will permit students to learn about construction technologies and methods, equipment and material usage, and the underlying tasks and their sequence.

2. Mode 2: Equally, the student can also browse through the construction equipment database and obtain information regarding the general specifications of the equipment, performance factors, equipment use and technology.

3. Mode 3: This mode is the interactive simulation and gaming mode. The system provides the student with real life construction scenarios, and permits him/her to develop and implement a solution, study the response of the system, and then iteratively improve the solution. A number of steps have to be followed by a student in this mode. At the outset, the student selects a problem scenario from the existing list displayed by the system. The system then provides the user with detailed explanations and data related to this scenario. In a second step, the student will then proceed to collect data and develop a solution for the chosen

scenario. This can be done using the construction process and construction equipment databases. The following step requires the user to implement his/her solution by developing a simulation model. The Interactive Learning System utilizes the Cyclic Operations Network (CYCLONE) modeling methodology (Halpin 1976) for the development of the simulation model. Finally, in the last step, the student collects the information generated by the execution of the simulation model. Steps 2 and 3 can be repeated to improve and eventually optimize the solution. Alternatively, the student can select an altogether different construction method as his/her solution and then proceed with steps 2 to 4.

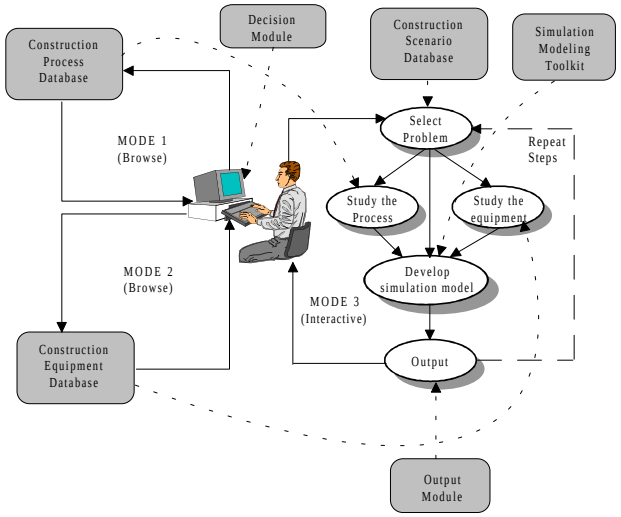

Figure 4: Student Interaction Process

The utilization of the Interactive Learning System intends to provide a problem-based cooperative learning environment for construction engineering and management education. It provides students with a practical laboratory and an opportunity to understand practical applications of the technical skills learned in the classroom. Further, students will benefit from practitioner involvement, will have the chance to improve their team skills, gain knowledge on construction equipment, construction processes and techniques, construction simulation, and the various interactions between these. It is planned to integrate the learning system into a series of courses in the undergraduate curriculum. Strategies to integrate the learning system into the curriculum of the following disciplines will be developed as part of this research project:

1. Civil Engineering - both at the lower and upper level of the undergraduate curriculum

2. Construction Engineering and Management- both at the lower and upper level of the undergraduate curriculum

3. Two-year Transfer Degree Programs in civil and construction engineering

6 CONCLUSION

The summary of the ongoing efforts and applications of computing for instruction clearly show the trends in education using computing and information technology. These tends are altogether understandable given the challenges educators and students face in instruction/learning nowadays. The Internet Based Interactive Construction Management Learning System also clearly caters to these needs by providing a system that permits active and interactive modes to improve learning effectiveness, a multi-disciplinary approach including knowledge on construction equipment, construction processes and techniques, construction simulation and the various interactions to reduce fragmentation and improve the students' use of their knowledge, and simulation to improve the students' understanding of the dynamics and complexities of the construction site. The value of such a tool in the current engineering environment can clearly be recognized, especially if one considers the simultaneous use of practitioner involvement from which students can profit in manifold ways ranging from guidance to improved industry knowledge.

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