Integration of Digital Photography and 4D Modeling in Undergraduate Construction Project Management Courses

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Abstract

Construction Project Management is diverse in nature and it does not lend itself easily to be presented in traditional lecture mode using blackboard and textbook readings. In addition, teaching this material always represents a challenge to the instructor because, for the most part, students lack experiential knowledge related to the subject. Therefore, there is a need to introduce experiential and group activities to support learning. Over the years, the author has introduced many features in his courses to create a simulated decision-making environment in which the students become directly involved in the planning and organization of resources allocated to the design and eventual construction of a project thus facilitating in this way the acquisition of experiential knowledge that goes together with learning basic principles and concepts that are fundamental in learning the subject. Among these features, there is a term project in which groups of students prepare a schedule and cost estimate of a hypothetical facility based on data taken from the development of a real project that was built or is under construction in the WPI campus. The use of Information technology in the form of visual material recorded from webcams during construction has facilitated the task of describing and analyzing the construction process. Integrating Building Information Modeling (BIM) in the form of 4D to the photographic material promises to add a new dimension that enhances communication and understanding dramatically and produces quantifiable information.

This paper describes the objectives, implementation plan and expected results derived from integrating digital photography and 4D Modeling in Undergraduate Construction Project Management courses in the civil engineering curriculum at Worcester Polytechnic Institute.

Keywords

Building Information Modelling, 4D Modelling, Construction Project Management, Design Constructability, Digital Photography, Construction Simulation, BIM in Education.

1. INTRODUCTION

The first author has offered the course CE3020 in Construction Project Management for more than 25 years at in the Civil and Environmental Engineering program at the Worcester Polytechnic Institute (WPI). The course is designed for civil engineering students with no background in construction project management. It is intended to provide a basic understanding of the concepts, principles, techniques, business methods and practices that are regarded central to the modern management of civil engineering projects. The principle focus of the course is the management of civil engineering projects. It includes among other concepts planning, scheduling, organization and control. For the most part as Table 1 shows it, students lack experiential knowledge related to the subject. Therefore, there is a need to introduce experiential and group activities to support learning.

Prior Level of Construction Knowledge and Experience	2008	2009	2010
None to Low	35%	40%	25%
Low – Medium	45%	39%	32%
Medium to High	15%	28%	30%

Table 1 Percent Distribution on Construction Knowledege and Experience from Students Taking the Class over the last three years

From the very beginning in the offering of this course, a term project was introduced to:

- Provide an opportunity to integrate material covered in the course into a more comprehensive exercise.
- Expose students to the implications of analysis and decision-making related to construction project management.
- Demonstrate the impact of the design on the constructability of the project.
- Illustrate the use of modern computer-based management tools in the planning, scheduling and control of construction projects.

This is an exercise conducted by groups of three or two students. It is developed in a span of six weeks throughout the term. It places the groups in a simulated environment for which the groups acting as a design-build firm, capable of preparing a lump-sum bid proposal, competitively bid (against other class groups) to provide professional services for engineering, procurement and construction (EPC) of a hypothetical facility to be built at the WPI campus. The preliminary architectural design for the building has already been developed. The proposal is evaluated in terms of the best combination of cost and schedule, that is, a schedule that meets the owner's specified completion date (or earlier) following a technically feasible sequence of work at the lowest cost. Also, the thoroughness, and completeness of the proposal document is heavily weighted in this evaluation.

The project gradually introduces material as class concepts are discussed. The concept of the Critical Path Method is presented in detail using simple example schedules of no more than 15 or 20 activities. Students learn to use basic features of PRIMAVERA software so they can assemble their networks with the aid of the computer and further learn how to set Work Breakdown Structures (WBS), activity cost and prepare cost loaded construction schedules. The first author developed a series of video-tutorials to supplement the students learning of the project management application software. After midterm, the students are handed a list of about 100 activities prepared by the instructor and are asked to develop a Critical Path Network diagram to establish the sequence of execution of the activities shown in the list. The teams first develop relationship diagrams for groups of activities within the same WBS category and then develop a relationship diagram for all activities in the project. This project relationship diagram is used to develop a network diagram using Activity on Node (Precedence) notation. This is the key part and most challenging submittal for the term project as the Table 2 (below) shows.

Over the last few years the students have been using actual material produced by the designer and builder of the Bartlett Center, the new WPI admissions office building completed in 2006, as the basis for the development of their term project. As of 2010, material from the current construction of the new WPI Recreation and Sports Center has been introduced into the course. To aid the students in this endeavor, students can view the actual CPM PRMAVERA schedule prepared by the contractor of the facility containing up to 400 or 500

activities. They can also look at pictures of the facility taken at different stages of construction. The contractor is invited to talk to the students and a field trip to the facility is scheduled

Areas of Difficulty	% of the Class
Developing a list of activities	26.3%
Creating a sequential schedule (critical path method)	**63.2%**
Types of costs (overhead, variable, wages, materials, etc.)	10.5%
Cost risk analysis	42.1%
Comprehension of activities	15.8%
Visualizing the logical process sequence	21.1%
Formulating an estimate of final costs	15.8%
Other	15.8%

Table 2 Percent Distribution on levels of difficulty experienced by students on different parts of the Term Project (Class of 2008)

too. These aids help conscientious students in learning about the project sequence of execution but it usually overwhelms most of the students with no previous experience, low motivation or limited time available to spend in this course. The use of Information Technology in the form of visual material recorded from webcams during construction has facilitated the task of describing and analyzing the construction process.

2. VISUALIZATING CONSTRUCTION

WPI unique educational system is known as the "WPI Plan" which among others educational characteristics it features a project-based education (WPI, 2011). As such students perform three major projects throughout their academic program. One of these projects is called the Interactive Qualifying Project (IQP) which is equivalent to three courses. Its main purpose is to develop an understanding of how science and technology are embedded in the fabric of society. The IQP challenges students to address a problem that lies at the intersection of science or technology with society (WPI, 2011). Through a coordinated set of two IQP projects titled Visualizing Construction (Bourque & Marois, 2007), (Jivanjee, 2008) a web-based resource was created to aid students taking the CE3020 course. This site uses visualization techniques to improve the students' understanding of the construction process. It shows the actual time-lapse videos taken form web-cams during the construction of WPI's admissions building, the Bartlett Center, so students can observe and study the actual construction process as it took place in real life. This resource aids engineering students interested in learning how to schedule different phases of the construction of a building project. The construction process was simplified and broken down into phases that could be easily comprehended by novice users and categorized into twelve major construction steps, from Pre-Construction through Close-out. Figure 1 below shows snapshots from this website (http://users.wpi.edu/~salazar/IQPMustansir/Website/testsite/homefinall.htm) at different stages of construction execution of this building. When the student clicks on the video file a step by step assembly of digital frames allows the student to observe the sequence and time of execution as well as the site logistics and resources that were needed to complete the project. Today, WPI students interact with the structure almost on a daily basis and some of them had the opportunity to observe its construction first hand during 2005 and 2006.

After the prototype website was completed, an on-line survey questionnaire was sent to CE3020 students who took the course between 2003 and 2007. The survey collected the students' views and assessment of the web-site on the basis of ease of use, functionality, effectiveness of visual aids, educational value, as well as about the value added by this resource in learning class material and in

executing their term project. The Survey results expressing student's views on the importance of visual learning and teaching are presented in Table 3 below.

Figure 1. Webcam shots showing different stages of construction of the WPI Bartlett Center

To what extent do you consider visual input important in improving your understanding of a subject?					
None	Some	Moderate	High	Very High	Total
0.0% (0)	0.0% (0)	20.0% (4)	50.0% (10)	30.0% (6)	20

Table 3. Student Perception of the Importance of Visual Input in Learning

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3. BUILDING INFORMATION MODELING IN CONSTRUCTION EDUCATION

The contributions of Building Information Modeling (BIM) in enhancing the educational mission of colleges and universities have been widely recognized by now. The BIMForum academic group identified the educational principles behind BIM related activities (BIM-Forum, 2007). A recent BIM-related Academic Workshop co-sponsored by the BIMForum and the BuildingSMART Alliance (Ecobuild, 2010) featured several papers in which BIM tools and techniques are now being used to aid in the visualization of concepts related to construction education (Clevenger et al, 2010), (Issa et al, 2010 and in particular using 4D modeling to support teaching about scheduling (Hyatt, 2010). Integrating Building Information Modeling (BIM) in the form of 4D to the photographic material promises to add a new dimension that enhances communication and understanding dramatically and produces quantifiable information. The following section describes the objectives, implementation plan and expected results derived from integrating digital photography and 4D BIM Modeling in Undergraduate Construction Project Management courses in the civil engineering curriculum at Worcester Polytechnic Institute.

4. BIM, 4D AND DIGITAL PHOTOGRAHY EDUCATIONAL MODULE

For many years now, the first author has been pioneering and actively promoting the use of Building Information Modeling (BIM), a powerful collaborative enabling technology and concept, in the civil engineering curricula at WPI. This work was initially done through graduate research projects and theses as well as Major Qualifying Project (MQP) activities. The MQP is a senior project equivalent to three courses that focuses in a civil engineering area. It involves a capstone design experience. The integration of BIM in the curriculum continues

today and to this date, about 50% of the MQPs developed by students in the civil engineering department use BIM to document and visually communicate their design and construction planning work. BIM activities in the program feature a 1-week-module in the CE1030 freshman class that is also included CE30030 AutoCAD course. A new course CE3031 has been recently introduced into the department's curricula. In this course the concept of BIM is introduced to the juniors as they learn how to use BIM tools through labs and a group term-project. This course also features three instructors from different design and construction management disciplines to demonstrate the collaborative nature of design and construction planning in civil engineering projects.

A recently completed MQP (Fournier et al, 2010) involved the development of a 4D model to visually track the construction progress of the new WPI Recreation Center which began in May of 2010. The project is scheduled for completion in August of 2012. This new Recreation Center will provide WPI with a competition length swimming pool, racquet ball and squash courts, 14,000 square feet of fitness space, a four-court gymnasium, indoor rowing tanks, and an extended three-lane track (WPI Sports and Recreation). The new Recreation Center provided the students with a real world laboratory to study the use of BIM, Earned Value Analysis (EVA), and scheduling coordination.

Given a 3-D BIM model of the completed construction, two different four-dimensional models were developed to contrast the projected and actual progress of the project. The first one displays the phased BIM model as it was scheduled at a given date and contrasts it with the actual progress as reflected seen in the webcam photo taken on that date. This picture was then used to create the second phased model reflecting the actual progress to date (See Figure 2). In addition to studying the construction schedule for the Recreation Center, an Earned Value Analysis was performed to compare the value of the work completed in each projected phase versus the amount of work completed in the actual phases. The calculations of quantities of work to perform the EVA are directly extracted from the BIM models.

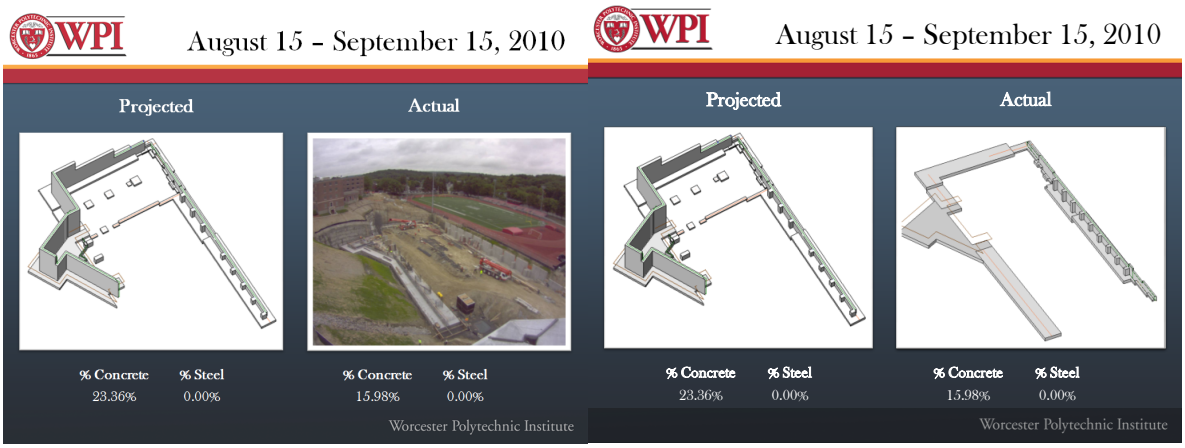

Figure 2, Webcam shot and 4D models reflecting scheduled progress and actual progress as of September 15, 2010

The above displays have been produced on a monthly basis for the contruction progress as observed up to February15, 2011. Works continues now with a second MQP (Belliveau et al, 2012) and an Independent Grdaute Study (Kaiser, 2011) to complete the monthly 4D set of phased models up to the completion of the facility.

In addition to the above 4D set of phased models, the webcam shots (Figure 3) correponding to the modeled phases of construction have been assembled and are made available to the students that as of the writing of this paper have started their term project for the current fall term 2011.

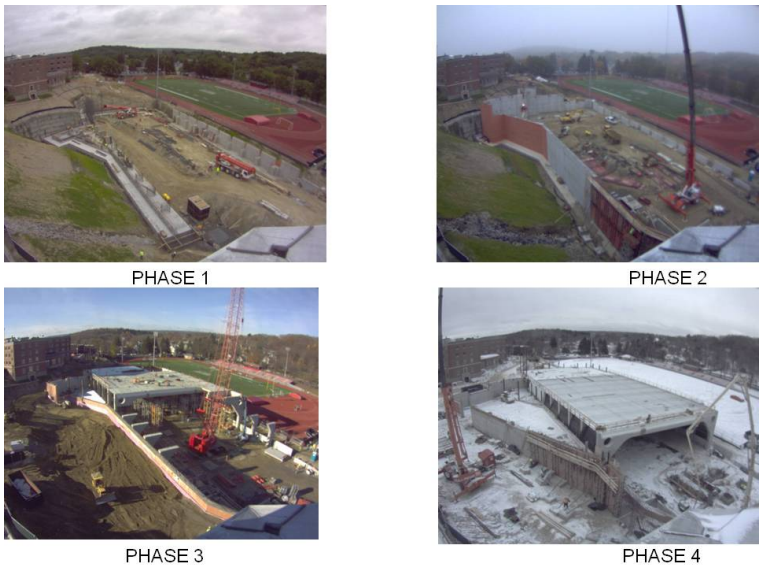

Figure 3. Webcam shots showing different stages of construction of the WPI Recreation and Sports Center

Finally, NavisWorks model integrating the phased models and the corresponding CPM schedule for the project has been created (Alvarez & Gomez-Lara, 2011). The model has been animated to facilitate comprhemesion and visualization of the relationship between the construction schedule and the phased 3D models. Fgure 4 shows a sccreenshot of an animated video display produced from this model (Kaiser, 2011)

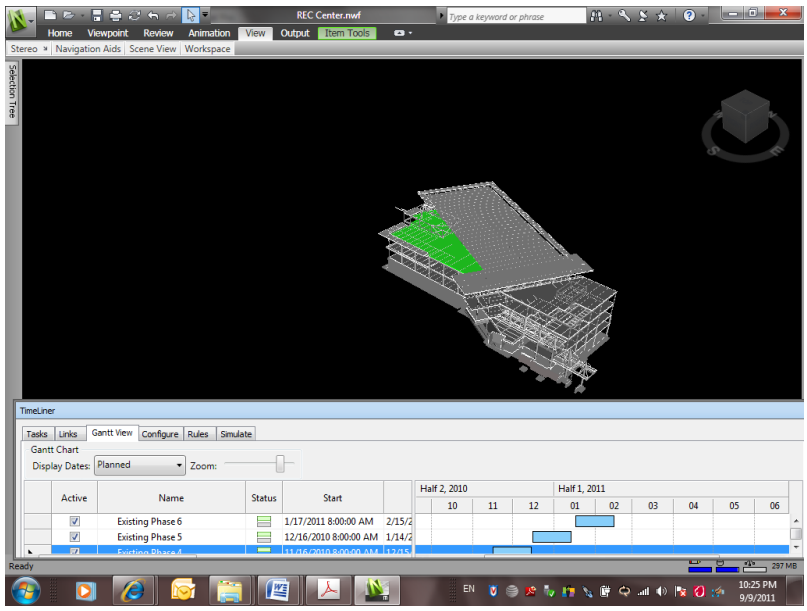

Figure 4. Screenshot of Aimated VidoeFile from NavisWorks 3D construction-schedule intehration

5. EXPECTED RESULTS

The 4D material herein presented has not been made available to the students currently taking the CE3020 course this fall semester. It is planned to do so shortly as they start their assembly of their CriticalPath Method network diagram. This dditional and very powerful resource should accmplsh two objectives:

1. Facilittate in a dramatic fashion, their understanding of how the different construction work packages and corresponding activities are sequenced in the real project. The students will still exercise judgment and be forced to analyze and discuss this material because the Level of Definition displayed in the 4D models does not necessarily correspond to the granularity of the list of activities they have been handed out by the instructor.
2. Motivate students to learn more about Building Information Modeling and to create expectations about its use and application not only for their rest of their academic activities, in particular for their MQPs but more importantly to create an expectation that BIM tools should be used in their future professional lives.

At the conclusion of the course, students will be asked to fill out a survey questionnaire to capture their perceptions and opinions of ease of use, functionality, effectiveness of visual aids, educational value, as well as about the value added by this resources in learning class material and in executing their term project. This survey will allow establishing a comparison and a more objective assessment of the improvement that take place in learning the material for this class.

6. CONCLUSIONS

After several years of experience promoting the use of BIM concepts at WPI, the invested effort in preparing and motivating students is paying off and it seems to that seeral discplines are coming together achieveing more integartion in the different areas of civil engineering.

The way in whihc the course CE3020 in Construction Project Managemnt as been delivered by the first author over the last 25 years or so has been gradually transformed by the use of Computers and Information Technology. Gone are the days in which the students developed their Term Project CPM network entirely by hand. With the advent of CPM software like PROMIS, PRIMAVERA and MS Project and their increased features and power, the students can concentrate more on the development of their networks and less on the cumbersome manual paper manipulations to display their network diagrams. Digital Photograhy and now BIM modeling tools have not only improve the functionality of the exercise but also contrinute in a powerful way to assist students in their learning of the subject.

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