USE OF BUILDING INFORMATION MODELING IN STUDENT PROJECTS AT WPI

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ABSTRACT

WPI Project-based education program known as the WPI Plan replaced the traditional rigidly-prescribed curriculum — typical of conventional engineering education — with a flexible, exciting, and academically challenging program aimed at helping students to learn how to learn. One of these projects, The Major Qualifying Project (or MQP) challenges students to solve problems typical of those to be encountered in their professional discipline. The concept of Building Information Modeling (BIM) promotes collaborative approaches for the planning, design, construction and eventual operation of facilities through the use of state-of-the-art information technology. Students use BIM tools to a varying degree in the development of their MQPs.

This paper describes the progressive use and applications of BIM in MQPs by students at the WPI civil and environmental engineering department. It reviews how integrated BIM tools are used and how BIM concepts have been incorporated into the development of projects. It also attempts to assess how well the use of BIM helps the students to attain WPI educational objectives and how it contributes to meet ABET program accreditation. Finally, it also examines the extent to which the introduction of the undergraduate course has impacted the use of BIM in projects.

Keywords: BIM, Student Projects, BIM curricula

1. INTRODUCTION.

In 1971, the WPI Project-based education program known as the WPI Plan replaced the traditional rigidly-prescribed curriculum — typical of conventional engineering education — with a flexible, exciting, and academically challenging program aimed at helping students to learn how to learn. The projects help students to identify, investigate and report on open-ended problems synthesizing classroom experience to solve real world problems. The projects also prepare students uniquely well for managing team efforts, and for communicating both in oral and written forms according to professional standards.

All WPI students complete two major projects in addition to requirements in general education and in their major fields. The Major Qualifying Project (or MQP) challenges students in their senior year to solve problems typical of those to be encountered in their professional discipline. The Interactive Qualifying Project (or IQP) is developed by the students in their junior year and presents an issue at the intersection of science, technology, and culture. It emphasizes the need to learn about how technology affects societal values and structures. Each of these projects is the equivalent of three courses and the MQP includes a capstone design experience. These design projects, advised by faculty, provide the students with an opportunity to showcase what they have already learned and learn new technologies. In many occasions the projects are developed by groups of two to four students.

The concept of Building Information Modeling (BIM) promotes collaborative approaches for the planning, design, construction and eventual operation of facilities through the use of state-of-the-art information technology. BIM was first introduced in the curriculum of the civil and environmental engineering department at WPI in the
early 2000s. This was done initially through graduate courses, projects and thesis but by the mid-2000s undergraduate students started to use BIM related software and some of the BIM concepts in their MQPs. In 2008 about 20% of the graduating class used BIM tools in their projects (Salazar & Conron, 2009). At that time a new undergraduate course was introduced to help students better understand BIM concepts and tools and to better prepare them in their use (Conron & Salazar, 2008). Since then, students have continued to use BIM tools to a varying degree in the development of their MQPs, however, a more formalized use of BIM concepts in their projects has been recently observed.

This paper describes the progressive use and applications of BIM in MQPs by students at the WPI Civil and Environmental Engineering Department. It reviews how integrated BIM tools are used and how BIM concepts have been incorporated into the development of projects. It also attempts to assess how well the use of BIM helps the students to attain WPI educational objectives and how it contributes to meet ABET program accreditation. Finally, it also examines the extent to which the introduction of the undergraduate course has impacted the use of BIM in projects.

2. BIM UNDERGRADUATE COURSE AND PROJECTS

In the early 2000’s, the Department of Civil and Environmental Engineering (CEE) at Worcester Polytechnic Institute (WPI) identified and anticipated the need for graduating students who could meet the increasing industry demand for skilled professionals and who could use and understand parametric object-oriented software in a collaborative fashion. The department has been gradually making adjustments in its academic curriculum to introduce content related to these concepts within the parameters of the institution’s educational plan. These adjustments have included graduate research, graduate courses, introduction of two modules into the Civil Engineering freshman course, inclusion of object-oriented parametric modeling in the junior graphics course, inclusion of modeling tools in the junior transportation course, and opportunities to use these modeling tools in junior and senior research projects (Salazar & Almeida, 2004; Salazar, Mokbel, & Aboulezz, 2006, Salazar & Conron, 2009).

This activity continues to expand. In the spring of 2008 WPI graduate students taking separate courses in Cost Estimating and Information Technology collaborated with graduate students taking a design studio course at the Boston Architecture College to develop a preliminary design for a train station in Natick, Massachusetts. This effort also involved collaboration and coordination of six instructors involved in the teaching of these three courses (Salazar, Vadney & Eccleston, 2010). In 2008, the department introduced the junior level course CE3031 Parametric Object-Oriented Software Applications in Civil Engineering to educate sophomores but mostly juniors and some seniors in the use of BIM related software within the context of Integrated Practice. This course combines four basic modules in Site, Architectural, Structural and Construction Planning throughout an integrated term project. In 2010, the graduate level course CE587 Building Information Modeling replaced CE585 Information Technology in the Integration of Civil Engineering. Graduate students continue to produce research each year by tackling more challenging topics related to BIM.

At the completion of the undergraduate CE3031 class a survey is administered to the students about the course. In the survey, there is a section related to their expectations for the future use of BIM. There are four questions in this regard which are next analyzed and discussed.

One of the questions relates to the use of Autodesk Civil 3D or Revit software for the Major Qualifying Project (MQP) as well as for other classes. The MQP is a project where the students deal with similar issues to those which they would face in the future, requiring the skills learned in the course.

For the question on the use of BIM in their MPQ, 48 out of 69 answered “Yes” and 7 answered “No” (See Figure 1), which implies that the application of a BIM tool seems to be perceived as a useful tool in the development of their project work. This expected use of the tool at the time the course is taken does not seem to correspond to the actual use of BIM in MQPs. Again, this may have more to do with the specific topic that is finally selected in their project, or perhaps the fact that not all faculty advisors in the department actively promote the use of BIM. It is important to note, that it may be too late for seniors taking the course to incorporate the use
of BIM in their projects. It has been observed that some seniors do not complete the course because they learn the material that is needed in the first weeks of the course and prefer to invest this time in the development of their MQPs.

Another question relates to expectations of the students taking this course to use BIM tools in another course. For this question 53 out of the 69 answered “Yes (see Figure 2). This answer reflects the perceived value that students may see for other classes. This may not necessarily happen once they take the courses since not all faculty incorporate the use of BIM in their course material.

The last question analyzed was optional and was answered by 37 students out of the 69 surveyed. This question ask students to identify reasons for which they would use BIM software in the future. The students were free to give more than one reason as an answer. Figure 3 displays these results. These reasons include that it could be a requirement in their jobs, and the second more selected answer was related with the fun of using this tool for work. Again, the answers reflected that after experiencing the use of the tools, the expectation and understanding of the tool increases. In addition, it reflects the increasingly computer-literate and dependent generation who are very comfortable with the use of technology and the fact they can relate much better to the building product.

3. ABET ACREDITATION

The Civil & Environmental Engineering program at WPI is accredited by the Engineering Accreditation Commission of ABET. The content and performance of the curriculum is developed to meet the accreditation requirements and is internally assessed in the context of the department’s Program Outcomes. There are 11 program objectives for which the department keeps track of its attainment by each of the students graduating from the program. The MQP plays an important role as the only vehicle for the students to meet the design capstone experience ABET requirement.

The use of BIM directly or indirectly contributes to the attainment of at least seven of the eleven program objectives, as follows:
1. Components of Civil Engineering Practice: Technical, Professional, Ethical
2. Preparation for the future changes in Civil Engineering
3. Understanding of Design Process, including the following: Ability to Perform Design, Multidisciplinary Aspects, Collaboration Skills, Communication Skills, Consideration of Cost, Consideration of Time Management
4. Understanding of options for careers and further education
5. An ability to learn independently
6. Broad education envisioned by the WPI Plan & described by the Goal & Mission of WPI
7. Understanding of the Civil Engineering profession in a societal and global context.

The last accreditation visit to WPI took place in 2008. At the time the use of BIM in the curriculum was loosely incorporated and its impact was not formally assessed by the accreditation committee. However, this impact assessment will be incorporated into the next ABET accreditation review. A broader discussion among the members of the department’s accreditation committee on the specific contribution of BIM into the curricula will certainly benefit from the concepts presented in this and previous papers on the subject. Potential extensions for student BIM certification have not been initiated yet.

4. MAJOR QUALIFYING PROJECTS

Graduating students from the Civil and Environmental Engineering Department are exposed to different discipline areas during the four years of their educational program. These include: Structural, Geotechnical, Transportation, Environmental, Urban Planning and Construction Management. However, they choose one of these areas as their preferred area to develop their MQP in more depth. When groups of students jointly develop their MQP, more than one of these areas may be developed in a coordinated fashion.

The Department first adopted the use of object-oriented parametric software tools for Qualifying Projects in 2005 and has continued to use these tools where applicable. Two software tools have been primarily used at WPI are AutoCAD Civil 3D (Civil 3D) by Autodesk and Revit Architecture and Structures (Revit) by Autodesk. This effort was spearheaded by one faculty member whose collaboration with few other faculty members contributed to encourage students to use these tools in their MQPs. In 2007 & 2008 about 70 percent of CEE faculty participated in three workshops conducted in conjunction with Autodesk staff. These workshops addressed the use of Civil 3D and Revit in the development of CEE curriculum. Since then there has not been any subsequent formal faculty training sponsored directly by the CEE department but an undergraduate course and a graduate course have been systematically exposing students to the learning of BIM tools. As a result, the uses of BIM in MQP development reflect more the initiative of the students than the active promotion of the faculty. This fact is reflected by the increasing number of MQPs in which students have been using BIM tools in the development of their work, as seen in Figure 4 below. In 2009 there were only three MQPs in which BIM was used contrasted to this past year of 2012 in which this number increased to nine. In total 27 projects used BIM in the last 4 years. As encouraging as this increased use of BIM tools is, the overall picture within the CEE department has not changed dramatically since 2008 when considering that the average percentage of MQPs over the last four years is 25% compared with 20% obtained between 2006 and 2008.

![Figure 4. MQP Projects Using BIM tools by year](image-url)
This lack of dramatic increase in the use of BIM tools by students MQPs can be explained in part by the lack of active promotion and involvement of the CEE Faculty with BIM tools. However, about 50 percent of the faculty advisors have supported the students’ initiatives of incorporating BIM as a tool to produce 3D graphic renderings of their designs. On the other hand, the level of depth and sophistication in which some students are now using BIM tools have significantly improved going beyond simple graphic documentation in 3D of their designs and including more involved interoperability of the building model with engineering software for structural and energy analysis using other software such as Scia by Nemetschek, Autodesk Robot, Green Building XML and Ecotect. The use of BIM in the construction management area has also become more sophisticated including 4D, 5D and 6D models with the incorporation of software like Navisworks, site and soil characteristics as well as exploration of the use of the BIM model for extensions in Facility Management applications. The next sections review some of the more notable uses of BIM in the recently completed student MQPs particularly those that were related to the design and construction of the recently completed WPI Recreation & Sports Center facility.

**New WPI Athletic Facility:** An Integrated Approach to Pre-Construction Practices. This project encompassed various limited pre-construction tasks, including conceptual design through BIM Modeling, structural design, construction feasibility, cost estimation, and investment analysis concerning Worcester Polytechnic Institute's new athletics facility within the context of Integrated Practice. Currently Integrated Practice is still young in development and has had limited exposure to the construction industry. The project determined that integrated practices can reduce errors, address issues earlier in design phases, and reduce construction times if specific project objectives, scheduling, and modes of communication are clearly defined. With proper implementation and organization, Integrated Practice can possibly become the standard method of construction in the future.

**WPI Recreation Center:** Construction Management and Alternative Design Analysis: This project provided an alternative design for the structural supports of the fourth floor of the new WPI Recreation and Sports Center. Using the information developed, a comparative analysis of the alternative design versus the current design was completed based on cost, feasibility, and dynamic response. Also, with information provided by Gilbane Building Co. and Cannon Design, two 4-D models of the project were completed. These models provided a platform to track and compare construction progress. In addition to the models, an earned value analysis was completed to further track construction progress and costs.
WPI Sports and Rec Center III: Construction Management and Constructability Analysis:
This project presents an alternative design to the earth-retaining structure to support lateral loading during construction of the foundation of the Worcester Polytechnic Institute new Sports and Recreation Center. The design was chosen based on soil profiles representing the earth surrounding the existing soil nail wall. Through the use of Building Information Modeling (BIM), students created a 3D model of the site to represent the existing conditions, mass excavation and total backfill of the different volumes of earth.

Enhancing Facilities Management and Structural Design through Building Information Modeling:
The project explored using Building Information Modeling (BIM) as a tool to provide continuity in the flow of information from the design/construction phases of the new Center to its occupation/operation by the WPI Department of Facilities. Three structural steel alternatives were designed, presented visually, and then compared to the precast arches located above the natatorium. A decision matrix was used to evaluate the structural options and select a preferred system. A BIM-prototype was created to demonstrate the capabilities of BIM for storage and retrieval of closeout documents and other critical information for the Department of Facilities. This system demonstrates the benefits of using information technology for facilitating the phases of construction and facilities management.
**UNUM Building Green Roof Study:** This project (See Figure 9 above) explores the impact of installing a vegetated green roof on the first office building of the new City Square Development in Worcester, Massachusetts. Potential LEED credits were considered in the design of the green roof, a structural analysis of the roof under the additional load was performed, and a cost benefit analysis was conducted. Building information modeling software was used to aid in the design process including the Revit Design Suite, and ROBOT Structural Analysis.

**WPI Recreation Center: Construction Management through 5D Building Information - Modeling with Alternative Design Considerations:** This project utilized Building Information Modeling to produce a 5-dimensional model of the WPI Sports and Recreation Center. The model was used to perform a construction schedule performance analysis of major work packages. In addition, alternative analysis and design was performed on the structural, geotechnical and functional aspects of the connection between Harrington Auditorium and the Recreation Center.

In this project the information generated by actual project’s Construction Manager was used to generate the 4D model using Navisworks software in an almost simultaneous fashion with the actual construction progress observed on the job. The BIM model was originally created by the designer firm and further adapted by the construction manager firm to conduct a 3D mechanical, electrical, plumbing, fire protection and structural coordination of these trades. The students attended the 3D coordination meetings and observed how did the CM integrated models provided by the subcontractors.

*Figure 10 WPI Recreation Center 4D Model by Baker, Beliveau, Sylvia and Williams (2012)*

**CONCLUSIONS**

It is evident that over the last four years, there has been a sustained effort to establish the use of BIM as a well understood and productive tool to support the development of MQP students’ work. The students taking the junior level course have certainly expressed their intentions to use BIM tools in that way and beyond. They also considered the learning these tools as a very important factor for future employment and career development. The extent to which BIM tools are used in the Department of Civil and Environmental Engineering at WPI is 25 percent on the average but is still expected to grow with time as more students take the junior level course and faculty participation increases. The encouragement and gradual adoption of BIM by the industry expecting students to acquire BIM skills and knowledge is also considered to be a strong motivator.

The level of sophistication and depth shown by those students who use BIM tools to support their MQP development work is increasing. Some students are now using BIM tools to go beyond simple graphic documentation of their designs in 3D and including more involved interoperability of the building model with engineering software for structural and energy analysis using other software.

The impact of using BIM tools in the curricula in the Department of Civil and Environmental Engineering has been clearly identified but it has not been formally assessed up to this point. This assessment will be incorporated as the department prepares for the next ABET accreditation visit to take place in 2014.
REFERENCES


Huard, J., Huard, W., McGinnis, D., Rodrigues, J., “Unum Building H Major Qualifying Project, Department of Civil and Environmental Engineering, Worcester Polytechnic Institute, April 2012


Moynihan, P., Olivieri, M., Weissman, M., “WPI recreation & Sports Center (3), Major Qualifying Project, Department of Civil and Environmental Engineering, Worcester Polytechnic Institute, April 2011

Munion, S., Stella, J., “WPI recreation & Sports Center (1)”, Major Qualifying Project, Department of Civil and Environmental Engineering, Worcester Polytechnic Institute, March 2011


