The Use of Object-Oriented Software in the Civil Engineering Curriculum and Undergraduate Projects at WPI

G.F. Salazar and C.E. Conron
Department of Civil and Environmental Engineering
Worcester Polytechnic Institute, Worcester, MA 01609

ABSTRACT - There are several object-oriented parametric modeling software packages available to help designers produce their increasingly more complex designs. The Civil Engineering department of Worcester Polytechnic Institute has developed a curriculum which includes a “Software Applications in Civil Engineering” introductory course as well as opportunities to further improve students’ modeling skills by using this software in the development of their junior and senior projects. This paper shows an increasing trend of using these software tools in undergraduate projects within the CEE department and the response of offering a course to introduce the students to the basic principles of the software.

I. Introduction

The Architecture/Engineering/Construction (AEC) industry is showing an increasing interest in the concept of Building Information Model (BIM) and its applications (Fauerbach, 2007; Strafaci, 2008). This interest has been fueled by the maturity and reliability of commercial software that supports BIM as well as by the concept of Integrated Practice which is now actively promoted by professional associations of owners, designers and builders. As a consequence, students graduating from colleges and universities are encountering an increase in demand not only for their skills in the use of this type of software but more importantly for their understanding and ability to function efficiently in collaborative and multidisciplinary professional environments.

In the early 2000’s, the Department of Civil and Environmental Engineering (CEE) at Worcester Polytechnic Institute (WPI) identified and anticipated this need and 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).

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. Most recently, an experimental undergraduate course,
CE203X Software Applications in Civil Engineering, has been introduced this fall to educate sophomores in the use of BIM related software within the context of Integrated Practice.

II. Background

Several object-oriented parametric modeling software tools exist today to help owners, designers, and construction mangers with intricate projects; however, shortages of engineers properly educated on the use of this sophisticated software hamper its successful implementation (Hannon, 2007). Students at WPI must complete an Interactive Qualifying Project (IQP) in their junior year and a Major Qualifying Project (MQP) in their senior year. 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.

Faculty members and students first adopted the use of object-oriented parametric software tools for Qualifying Projects in 2005 and have continued to use these tools where applicable. Two software tools currently used at WPI are AutoCAD Civil 3D (Civil 3D) by Autodesk and Revit Architecture and Structures (Revit) by Autodesk. A sample of past and current projects using Revit and Civil 3D is provided below.

Examples of Past Student Projects

IQP: E-Buildings: An Information System for Facilities Management on the WPI Campus. This project was developed to incorporate data and information collected in previous IQP projects that were related to campus fire safety. This resulted in an enhanced 3D information system for the Plant Services department at WPI. The students used Revit software to create 3D models of different building within the campus and link these models to an AutoCAD DWG file representing the entire campus site (Figure 1). The basic information was stored in Microsoft Access and Excel databases and also linked to the 3D models. This system demonstrates the benefits of streamlining current processes used to maintain safety within a college environment. The project was advised by two faculty members from different departments and the director of WPI Physical Plant (Brault, Krol & Molineaux, 2005).

Figure 1. WPI Campus linked to 3D different building models (Brault, Krol & Molineaux, 2005).

MQP: Construction Management Services for the new WPI Residence Hall. This project presented an alternative design for the foundation wall of the Worcester Polytechnic Institute new residence hall to resist lateral loading during construction. The cost implications of this alternative design were also investigated. A 3D model (Figure 2) of the structure of the building constructed using Revit software and a quantity takeoff was developed using this model. A manual cost estimate and takeoff for the structure was also performed and compared to the quantities generated by the model.
Examples of Current Student Projects

MQP: Integrated Practice: Preliminary Design of the WPI New Recreation Center. The design of a new recreation facility at the WPI campus has been initiated. The architects are completing the architectural program and are ready to start the conceptual design of this facility with the assistance of the construction manager. The student project will mimic this process within the context of Integrated Practice using BIM related software (Civil 3D, Revit Architecture and Revit Structure). They will produce their own version of the schematic design and structural analysis together with preliminary estimates, schedules, constructability reviews and life-cycle cost analysis. The students will attend weekly owner-architect-construction management meetings as the real project developers. The MQP project is being developed by three civil engineering students and two management students advised by three faculty members representing both departments (Bernand, Blanck, Grant, Petrocchi, & Sealunk, in press).

MQP: Smart Pavements. This project will design an underground pipe network which will transfer heat energy from pavements to buildings for use in heating and cooling systems. This project’s main focus is the design of the pipe network. This project will capitalize on the Google Earth/Civil 3D interoperability to create a base plan and design a pipe network to transfer heat energy for the WPI campus (Lee, Richardson & Anthony, in press).

IQP: Redesign of Downtown Canton, Maine. This project’s goal is to evaluate a parcel of unused land in downtown Canton, Maine and suggest land use alternatives. This project is using the Google Earth/Civil 3D interoperability feature to obtain base plans for the analysis. This project plans to also use Revit to generate renderings of any proposed alternatives which include developing the unused land with buildings (Mattern, Auer, Lacagnina, Munoz, & Nido, in press).

MQP: Re-Design of Burncoat, West Boylston, and Mountain Streets. This MQP team is tasked with the evaluation, analysis, and re-design of two closely spaced intersections in Worcester, Massachusetts. The solution may involve traffic signal re-timing or geometric improvements. The project team plans to use Civil 3D and Google Earth to evaluate the feasibility of geometric improvements (Keck, Schultz & Serra, in press).

III. Growing Demand for Parametric Object-Oriented Software In Projects

An increasing demand for the use of object-oriented parametric software tools in undergraduate projects has been observed since it was first used for this purpose in 2005 (Figure 3). Seniors have increased their use of these tools (Revit and Civil 3D) in their MQPs from no use to 20 percent of the graduating class. This trend is expected to continue in the future.
IV. Introduction of New Course

In response to the increasing use of object-oriented parametric software through the AEC industry and the CEE curriculum, the WPI CEE department has recently added an experimental “Software Applications in Civil Engineering” course to instruct students on the basic use and concepts of object-oriented parametric modeling software within the context of Integrated Practice. This course intended primarily for sophomore students provides them with fundamental skills for the use of this software and gives them an understanding of design components through 3D visualization. It also gives them an awareness of the importance and value of analysis and design courses as well as an appreciation for collaboration and communication within multidisciplinary professional practice. This course allows students to develop a perspective to identify future challenges and opportunities for the use of this software in their courses and qualifying projects.

This course introduces students to the BIM concept from the entire AEC industry perspective. It covers the basic principles of modeling through object-orientation, style and parameters. The multi-disciplinary team concept is covered in this software course by exposing the students to site and road design, preliminary architectural and structural design, as well as construction planning and preliminary cost estimating. These activities are supported through the use of Civil 3D, Revit Architecture and Revit Structure; the interoperability among these packages; and interoperability with other software applications such as GIS and spreadsheets.

Both Revit and Civil 3D are used to discuss model exchange techniques from planning through construction and operation of facilities. Emphasis is given to the discussion of basic modeling software capabilities and their relation to more powerful built-in
analytic and design capabilities not necessarily covered in the course. Writing and oral communication skills, which are an integral part of successful team practice, are also covered.

The students work in groups to integrate the different components of the course through a case study in which they develop the site and present the preliminary design and construction planning of a warehouse facility. The students respond to an “owner’s” Request for Proposal making a final presentation of their work and submitting a report.

V. Extended Use of Software Tools

The WPI CEE department has identified that approximately 50 percent of the courses currently offered to undergraduates could integrate an advanced Civil 3D module and approximately 33 percent of the courses could integrate an advanced Revit module. Thus building on the concepts introduced in this course, while complementing each individual course’s objectives. One example of this integration is the use of Civil 3D in CE3050: Transportation Engineering and Design. A Civil 3D module was added to this course in the fall of 2007 to complement the instruction of highway design with state-of-the-practice highway design tools.

VI. Results and Conclusions

The first version of the experimental course has just been finished. Twenty students took the course including eleven seniors. As said before, this course is intended primarily for sophomore students, but apparently some seniors found the topic interesting and took this course since no course of this type has been offered by the department before. It is important to note that most seniors are in the process of completing the first third of their MQP work with two thirds to go. Students still have an opportunity to apply their recently acquired knowledge of the software to their MQPs.

An exit survey questionnaire was administered to the students at the end of the course. Three simple questions were included to determine the expected future use of the material covered in the course. The results are shown below in Figure 4.

![Figure 4. Student’s Distribution of Expected Future Use in Curriculum.](image)

It can be observed that a vast majority of them (about eighty percent) intend to use the software in the future because they see it mostly as a productivity tool. The rest (20 percent) intend to use it only if academic credit is given. Although these questions are not proving enough to determine in more detail the motivation behind the students’ answer to the survey, it is encouraging to find that the students leave the course with the impression that what they have learned has future value in their immediate academic activities at WPI which certainly include Interactive Qualifying Projects for sophomores and juniors and Major Qualifying Projects for all of them.
Another encouraging element that may help to reinforce the positive expectations on potential future use of the material learned by the students in this class is the participation of about 70 percent of CEE faculty in three workshops conducted over the last two years with Autodesk staff. These workshops addressed the use of Civil 3D and Revit in the development of CEE curriculum. A recent survey conducted among the CEE faculty also provide encouraging evidence for future use of the software in courses and projects as shown in the Table 1.

Table 1. Faculty Survey Results.

<table>
<thead>
<tr>
<th>Past and Future Use of Software</th>
<th>Percent Faculty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Used software before CEE software workshops in Courses and/or Projects and will continue to use it in the future</td>
<td>29 %</td>
</tr>
<tr>
<td>Have not used software before CEE software workshops in Courses and/or Projects but will use it in the future</td>
<td>29 %</td>
</tr>
<tr>
<td>Have not used software before CEE software workshops in Courses and/or Projects and will not use it in the future</td>
<td>12 %</td>
</tr>
<tr>
<td>Have not used software before CEE software workshops but students have used on their own. Will not promote or discourage use in the future.</td>
<td>6 %</td>
</tr>
<tr>
<td>Did not Reply</td>
<td>24 %</td>
</tr>
</tbody>
</table>

Active participation of the faculty is essential to successfully teach students the use of this software and the value of collaboration and integrated practice for their future careers.

VI. References


