Collaborative Term Project between Worcester Polytechnic Institute & Boston Architectural College

Guillermo F. Salazar
Worcester Polytechnic Institute
Worcester, MA, 01609
salazar@wpi.edu

Timothy J. Vadney
Worcester Polytechnic Institute
Worcester, MA, 10609
tjvadney@wpi.edu

David Eccleston
Boston Architectural College
Boston MA
deccleston@the-bac.edu

Abstract

In December of 2007, the faculty of the Civil and Environmental Engineering Program at Worcester Polytechnic Institute (WPI) and the Boston Architectural College (BAC) recognized the limitations of their own single discipline program orientation in teaching BIM concepts to their students and taking advantage of the relative proximity between the cities of Worcester and Boston in Massachusetts decided to experiment in creating a multidisciplinary educational opportunity by developing a collaborative term project as part of the course requirements for three graduate courses offered independently but simultaneously during the spring semester of 2008. These courses were BAC's CD102/CD102A Integrated Design Studio, WPI's CE584 Advanced Cost Estimating and CE585 Information Technology in the Integration of Civil Engineering. The experience was supported by the use of remote information technology as well as by promoting personal contact among students and faculty. The lessons learned from the experimental offering of the course were assimilated and incorporated in the offering of these courses in the spring semesters of 2009 and 2010. This paper describes the objectives, implementation plan and results derived from this collaborative academic effort.

Keywords
Building Information Modelling, Collaborative Design & Construction, Preliminary Cost Estimating, Design Constructability, Remote Collaboration, Design-Construction Integration, BIM in Education.

1. INTRODUCTION

Teaching the multidisciplinary aspects of Building Information Modelling (BIM) to students within the context of a given academic disciplinary program becomes very challenging in the sense that the professional expertise and practice is mostly limited by the instructor's personal background and experience. A solution to overcome this limitation is often found in inviting guest speakers from other disciplines who present their views and experiences from their own perspective. This approach gives the students an awareness of multidisciplinary issues of BIM practice but does not provide enough personal experiential opportunities to develop insights for the students. Some large colleges and universities offering architectural and engineering programs in the same campus are able to create collaborative multidisciplinary learning experiences for their students. Use of Information Technology also allows students from different programs and locations to collaborate in academic activities but still deprives the students of the opportunity to have a personal contact with the students of the other disciplinary program.

In December of 2007, the faculty of the Civil and Environmental Engineering Program at Worcester Polytechnic Institute (WPI) and the Boston Architectural College (BAC) in a joint presentation at Build Boston (Cherney et al. 2007) recognized the limitations of their own single discipline program orientation in teaching BIM concepts to their students At the time, BAC was exploring how the use of BIM and Integrated Practice could change the way in which BAC students could learn to be better architects, both inside the classroom as in firms as emerging professional. On the other hand, WPI construction management program offered by the department of civil and environmental engineering department program has been gradually integrating the use of BIM in some courses, project and thesis (Salazar & Conron 2009), (Conron & Salazar 2008), (Salazar et al. 2006), (Salazar et al. 2004), (Salazar et al. 2001). Therefore, the faculty directly involved with BIM at both institutions considered the advantage of the relative proximity between the cities of Worcester and Boston in Massachusetts as well as the advantages offered by Information Technology to support remote communications and decided to create a multidisciplinary educational opportunity by developing a collaborative term project as part of the course requirements. This was done initially for three graduate courses offered independently but simultaneously during the spring semester of 2008. These courses were BAC's CD102/CD102A Integrated Design Studio, WPI's CE584 Advanced Cost Estimating and CE585 Information Technology in the Integration of Civil Engineering**.** The lessons learned from the experimental offering of the course were assimilated and incorporated in the offering of two of these courses, CE584 and CD102/CD102A in the spring semesters of 2009 and 2010.

2. OBJECTIVES

From the very beginning, it was decided that the individual educational objectives of each of these courses should be attained as originally planned but in the context of joint collaboration between the designer (BAC students) and the construction manager (WPI students) who were to provide pre-construction services (Preliminary Cost Estimating, Scheduling and Constructability Analysis) during the schematic design phase of a simulated project. In addition the use of BIM tools and the creation of a BIM model were required for the CE585 students in 2008. Because of the nature of CE584 and CD102/102A students taking these courses have been strongly encouraged to use BIM models and tools in the development of the design and construction management related academic activities. The use of BIM tools by these students has been gradually increasing.

In each of the three years in which the collaborative term project has been developed by the WPI-BAC students, their work has been delivered in terms of a joint report containing several components. These components have changed in scope and detail as shown in Table 1.

For the spring of 2009, the objectives were the same as in the previous year although CE585 participation was no longer included because the course was in transition and was not offered that semester. We added to the methodology as building on the 2008 year lessons learned

For the spring 2010 studio the primary focus of the Boston Architectural College (BAC) was collaboration. The BAC is keenly interested in collaboration as part of the design process both within the design studio and office as well as, in this case (Spring 2010), with other disciplines outside of the studio.

There were two primary objectives for this studio. The first was to have the BAC studios interact with the WPI students in a way that make the projects more realistic from a cost and constructability perspective while enriching the process with an additional layer of

information and therefore creating a more sophisticated and resolved project than may have been possible without the collaboration.

Design (BAC)	2008	2008 (CE585)	2009	2010
Site Plan	Yes		Yes	Yes
Architectural Floor Plans	Yes		Yes	Yes
Structural Framing	Optional		Yes	Yes
Final Elevations	Yes		Yes	Yes
Wall Sections & Interior Elevations	No		Optional	Yes
Ceiling Plans	No		Optional	Yes
Finish, Door & Window Schedule	Optional		Optional	Yes
Major Equipment List	No		Optional	Yes
Mechanical/Plumbing/Electrical Drawings	No		No	Yes
BIM Model	Optional	Optional	Encouraged	Yes
Construction Management (WPI)				
Constructability Analysis	Optional	Yes	Yes	Yes
Preliminary Cost Estimate	Yes	Optional	Yes	Yes
Construction Schedule	Optional	Yes	No	No
BIM Model	Optional	Yes	No	No
4D Model	No	Yes	No	No
5D Model	No	Yes	No	No
6DModel	No	Yes	No	No

Table 1 Design and Construction Management Joint Deliverables

The second primary objective was defining the methodology of collaboration. This methodology consisted of both the planning and organization of the project and process as well as the specific tools that would be used to implement this plan. The primary tool for this would be a BIM model that the BAC students would create and maintain for this objective.

3. METHODOLOGY

To accomplish the objectives for each course involved in the collaborative project each instructor needed to make some adjustments in the way they delivered the course. They also needed to coordinate these with the other instructors so the joint needs of the collaborative project could be accommodated. The instructors involved additional consulting staff for their courses to provide technical and professional support for the term project. The instructors also had to contend with the varying number of students enrolled in each course and their corresponding background, professional experience, motivation, availability, commitment and familiarity with the use of BIM tools which included primarily but not exclusively Autodesk Revit Architecture software.

Due to the academic requirements of the BAC program, each student enrolled in the course was required to develop their own design proposal. This was an interesting concept that eliminated the possibility of having the WPI engineering students becoming co-designers of the project which given the highly interactive and collaborative nature of BIM methodology and integrated delivery methods such as Integrated Project Delivery (IPD) may, in the future, be challenging this academic requirement. However, WPI students in the context of this project were expected to provide primarily construction management services but were not necessarily limited to these creating the opportunity for also providing design/engineering

expertise for those who already have it. This was the factor controlling the number of groups and the distribution of BAC & WPI per group. For example in 2008 due to class sizes the methodology was to group each a single designer with a group of WPI estimators (CE584) and a student from (CE585) to develop a design, estimate, and constructability report. The final team size ratios were 1 BAC, 3 CE584, and 0.5 CE585, see Table 2 below,

ITEM	2008	2009	2010
WPI CE585: Number of Students	3	None	None
WPI CE584: Number of Students	21	12	6
BAC CD102/102A: Number of Students	7	4	6
Number of Groups	7	4	6
Group Ratio CD201/102A/CE584/CE585	1/3/0.5	1/3	1/1

Table 2 WPI-BAC Group Student Ratio

Each year, the project object of the design was different, however the location of the site was local so it could be visited and researched directly. In 2008 the project involved the remodeling of a train station in Natick MA. In 2009, it was the sailing pavilion in Boston MA. In 2010, it was decided that the project should be a common building type for which there would be ample precedents, information and expertise available and the North Allston elementary school was selected. In all cases, at the beginning of the term, students and faculty from both institutions arranged for a joint visit to the actual site of these projects to get to know each other personally and to collect information about the site characteristics both for the purpose of the design and the construction planning of the project. Students asked questions that began to make them aware of the unique perspectives each group brought to the table and the unique goals that would have to be reconciled as the designs began to take shape. The students were allowed to pair up on their own and they exchanged contact information.

After the first meeting, the BAC students entered into a schematic design phase for approximately 4 weeks at which point they published their designs for comment to the WPI students. Due to the highly compressed nature of the design process for this studio, it was decided that the BAC students would produce schematic design with whatever methods they traditionally designed in and would not begin production of the BIM model until the design development phase. The schematic designs that were produced ranged from hand sketches on trace and small sketch models, to traditional CAD models and drawings, to very basic BIM models, where the BIM was used primarily as a massing and drawing tool without regard to embedded data. The schematic design was communicated electronically to the WPI students primarily through scans, digital photos and PDFs. The data was exchanged through WPI's web portal Blackboard and WIMBA or through email attachments. The WPI students then began to give some basic general comments back to the BAC students. It was this first round of feedback that most significantly influenced the design for the majority of the projects. Although the comments were fairly basic, they tended to be more overarching at a time when the design was still fairly fluid and the students had not yet begun to construct detailed BIM models. For example, comments or feedback on the number of floors or the construction type could still be considered in the design.

Around mid-term, students presented their schematic design at the BAC facilities to all the instructors and to each other. After this presentation, the design development phase started and it would last for approximately 4 weeks after the conclusion of schematic design. Over the next several weeks the communications cooled down as the BAC students focused on building their BIM models. For many of them, this was their first significant experience with

BIM. The BAC had provided a teaching assistant that acted as the BIM tutor giving short lessons the first few weeks and providing specific out of class time for tutorials and one on one tutoring. WPI students then took the schematic design and dissected it to determine means and methods for construction, conducted a constructability analysis of the design identifying missing elements, suggesting and discussing alternative design options with the architectural students to facilitate construction and reduce cost. After several weeks of developing the BIM models, with the deadline approaching, the designs began to solidify. The added task of maintaining a BIM model for others' use became a significant time issue with more and more focus on the BIM deliverable and less focus on exploring specific design issues. After delivery of the BIM model to the WPI students there was another round of significant feedback before the students presented jointly at WPI. This feedback primarily consisted of cost/square foot numbers and specifics that were driving any unusual results. While the WPI students finished their reports, the BAC students focused on presentation material.

A final joint presentation of their design/construction planning/BIM models was made at WPI's campus by each group at the end of the WPI spring term. Then a final discussion about the experience was conducted with all the students and faculty involved in the term project group/faculty. BAC students continued to working in their designs for a few weeks more until the end of their spring semester. During the summer, faculty from both institutions conducted discussions to assess results and to make adjustments for the future.

The BAC-WPI level of interaction during the second phase of the term project was very different in 2008 in when the CE585 students were primarily responsible for the construction of the BIM model due to the nature of that class. In that year, this was the highly interactive part of the term project in which BAC-WPI students exchange ideas and solutions using primarily but not exclusively electronic discussion boards, email correspondence, web-based interactive sessions, telephone calls and occasional face-to-face meetings. In all this students from both institutions make heavy use of the Blackboard system at WPI called MyWPI which is also used for electronic file exchange posting. BAC students modified their designs accordingly and WPI students produce final cost estimates. BIM tools and BIM models were used to extract information for floor area quantification as well as for building component schedules (windows, doors, and structural components). In 2008, CE585 students also produced construction schedules and combined the BIM model with these schedules and the cost estimate to produce 4D and 5D corresponding models.

4. RESULTS

The results and experience derived from the work conducted over the last three years are discussed next.

4.1 Spring 2008.

Sample reports are showing next to illustrate the work jointly produced by the students. Figure 1 shows the only design fully produced using BIM tools in 2008. The type of project led to a variety of designs and level of construction input for each of them. The cost estimates for all seven designs ranged from $ 2.1 M to $ 22.4 M which shows that designers were not particularly concerned with meeting a budget for the project, which by the way was not a requirement to be met by the design criteria. However, the fact that preliminary cost estimates and constructability analyses were conducted gave designers an opportunity to discover the cost impact of their designs.

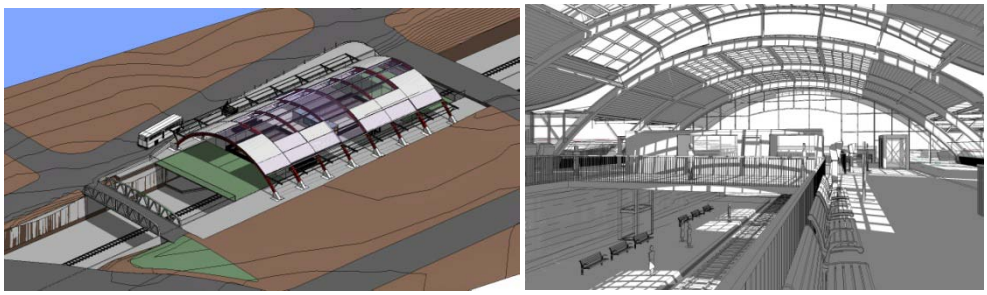

Figure 1 BIM Model developed by A. Gomez (BCA) , A. Petrocchi, C. Keegan, B. Skelcher (CE585) N. Alborzfard, C. Powers, (CE584)

There was less detail in some of the final designs which caused some of the estimates to be more of a conceptual study rather than a final design development estimate. The accuracy of the final design and pricing was not the main criteria. We were looking to demonstrate the process of interpretive collaboration and focus on communication between two groups of professionals to add information from their respective specialties.

Although all students, professors, and reviewers agreed that the first pass was successful they also agreed to further refine the process. Some of these lessons learned pointed to earlier design models, more information in the model and less diagrammatic sketches, project had some additional unique challenges in terms of maintaining an operating commuter rail amongst construction on both sides of the site. Some design elements were not economically feasible and more focus on the value engineering collaborative process should be explored in the future. During the process the students used a blend of software solutions including Sketchup, Revit, Sage Timberline, On Screen Takeoff, and Adobe Acrobat.

4.2 Spring 2009

The designs were able to be developed to a high level of BIM integration than the first year due to introducing the teams much earlier in the semester. The class was a combination of lecture and collaboration which was successful in providing a much higher level of design and better cost estimates. This semester the CE584 students were also responsible for constructability reviews and various value engineering sessions to be held in conjunction with the model building. The lesson learned from the second collaborative session was the type of project again was very unique and brought in design elements such as cofferdams and seawalls making the site more difficult to analyze without the additional input from various design engineers. The WPI students filled this role but the actual engineering was out of the scope of the course. We held a lessons learned session and discussed making the project more vanilla boxed, i.e. hospital, school etc.

4.3 Spring 2010

From a design perspective, supporting the BIM model caused an uneven design process. The designs were rushed through schematic design at some cost to the critical process. Once the construction of the BIM model began, students were apprehensive to make design decisions that would un-do the BIM model. These are very real pressures in an office environment but are pressures seldom felt in the academic studio. The feedback did not create enough opportunities to offset this, resulting in designs that tended to be more grounded though not as critical as you might get in a traditional design studio.

During the estimating phase of the collaboration the WPI students were fully engaged in gathering the various levels of models and both schools respectively communicated well with one another to develop the designs. Although the early BIM models certainly lacked

sufficient detail to complete a conceptual estimate from the model alone it was an overall advantage to have access to the 3D data and information contained therein.

The BIM software was understood by the students in the studio environment much faster than in a software instruction class and the breadth of that understanding was much greater. This was primarily due to the fact that the software was learned during a design process that developed unique and unforeseen problems rather than in a class where there are specific tasks presented in specific order over regular periods of time. The students quickly developed an extensive understanding of the software and its capabilities and this grew with each problem presented, whereas students taking a software class, tend to be task-oriented, drawing only from the specific tools given to them rather than developing unique solutions for unique problems.

Although the students were provided with a collaboration site on the WPI network, most students tended to use ad-hoc methods for collaborating as they were primarily emailing and doing simple file transfers. Also the BIM information only went in one direction. The BIM models were used by WPI students to study the building and to extract data, but none of the unique information provided by them flowed back through the model. Instead it came through more traditional electronic documents (word processing, spreadsheets, PDFs, etc.) through email. This meant there was little need for the students to maintain a single point of reference for their files or models; the latest received was the latest.

If the students had to collaborate in the BIM model they would have needed either a more robust environment to share the model remotely and simultaneously, or lacking that, would have to organize the model and the process so they had a composite model that was updated on regular established intervals, thus being virtually live if not up to the minute.

It would also be beneficial for the BAC students get more regular feedback that they can engage more fully from the point of design. It was discussed at the final presentation that perhaps having structural engineering students collaborating with architecture students would encourage the architecture students to take more risks and then work through those issues producing a unified model that is fully owned by both parties.

5. CONCLUSIONS

After three years of experience conducting the collaboratie term project with the faculty and students of both institutions it can be concluded the learning that has taken place and the benefits the students have derived from the experience outweighs the amount of faculty effort and coordination efforts involved in such an ambitious project. An infrastructure is in place now to continue with this collaboration. Additional experience is gained each year allowing the faculty toidentify areas for continuous improvement and better efficiency.

BIM tools and concepts continue to gain ground in our industry and educational system the students shall be able to "dig deeper" into the collabrative aspects and nature of the BIM approach. As BIM becomes more and more prevalent and students develop more sophistication earlier in their education, the issues of providing BIM support and training in the studio will be alleviated and more time can be spent on design. This will also make students more receptive to the kind of regular changes that collaboration can introduce to the design process.

The issue of collaboration has always been an essential element of this term project, however, the lessons learned over these three years have allowed the faculty to better understand the interactions among all involved and make them better structured and more efficient.

The development of the BIM model has become primarily the responsibility of the BAC students. This has caused the level of interaction between students of both institutions to diminish during the second phase of the project.

6. ACKNOWLEDGEMENTS

The authors wish to explicit acknowledge the direct contributions and ideas from individuals who have enriched and made possible the implementation of this collaborative project. We want to thank Leonard Cherney, Andrea Saavides, Karen Nelson, Amy Chang, Hala Mokbel, Kate Beverage, Christine Conron, Chris O'Connell, Patrick Reffett, William Kearney, Ralph Stokowski, and all the BAC and WPI students who have taken these courses and worked diligently in their term projects.

7. REFERENCES

Charney, L., Millett, J., DiRocco, D., Fertig, J., Quinn, A., Salazar, G., 2007, "BIM Integrated Practice, and Education of Students and Young Professionals",panel presentation at the Build Boston Conference November 15, 2007.

Conron, C., & Salazar G., "Incorporating AutoCAD Civil 3D and Revit into Higher Education", *Proceedings of the Autodesk University Conference, Las Vegas NE, December 4, 2008*

Salazar G., & Conron, C., "Introduction of Object Oriented Software into Civil Engineering Curriculum through Undergraduate Projects at WPI", *Proceedings of the ASEE Engineering Design Graphics Division 63rd Midyear Conference, Berkeley, CA, January 5, 2009.*

Salazar, G., Mokbel, H., Aboulezz, M., 2006, "The Building Information Model in the Civil and Environmental Engineering Education at WPI", *Proceedings of the ASEE New England Regional Conference, Worcester, MA, March, 2006.*

Salazar, Guillermo F; Almeida, Joao C., 2004 "Use of the 3D Parametric Building Model in Civil and Environmental Engineering Undergraduate Education at WPI," *Proceedings of ASEE Annual Conference & Exposition: Engineering Education Reaches New Heights; Salt Lake City, UT; USA; 20-23 June 2004.*

Salazar, G., Polat, I., and Almeida, J., 2003 "The Role of the 3D Parametric Building Model in the Future Education and Practice of Civil Engineering and Construction", *Proceedings of the ASCE IV Joint International Symposium on Information Technology in Civil Engineering, Nashville, TN, November 15-16, 2003.*