ABSTRACT

The Penn State Stuckeman School of Architecture and Landscape Architecture along with the Department of Architectural Engineering have offered the Interdisciplinary Collaborative BIM Studio since 2009. This multidisciplinary studio involves students from all six of the major building design and construction disciplines (architecture and landscape architecture as well as construction, structural, mechanical, and lighting / electrical engineering). In conjunction with other BIM related course offerings at Penn State, the BIM Studio has been the recipient of four national awards.

In the BIM Studio students form six person multi-disciplinary teams to design a project based on a real site and program. Projects are selected to facilitate interface between the student teams and the actual project design and client team. Students use not only BIM technology for design integration and analysis but also Integrated Project Delivery (IPD) processes for collaboration.

In this paper instructors of the Interdisciplinary Collaborative BIM Studio will overview the development of the studio course, integration into the curricula of three departments, overview course feedback from students and participating practitioners, reflect on the challenges and opportunities of offering multidisciplinary BIM courses as well as the potential for interface with the AEC industry for IPD / BIM related research.

Keywords: BIM, IPD, Interdisciplinary, Collaboration, Accreditation, Changing Profession, Comprehensive Design Studio

1. COURSE DEVELOPMENT AND CURRICULUM INTEGRATION

The Interdisciplinary Collaborative BIM Studio (ICBIMS) will be offered for the fifth time during Spring Semester 2013. This innovative studio has been the recipient of four major awards including two American Institute of Architects Technology in Practice Awards (2010, 2012). In addition to the use of BIM technology this studio has three other important characteristics:

- Interdisciplinary Collaborative Design Teams: Each team has six students one each from architecture, landscape architecture and the four Penn State AE disciplines (construction, structural, mechanical and lighting / electrical engineering). Based on our research, we believe this is the only academic design studio in the United States that integrates all major disciplines involved in project design and construction.

- Practitioner / Client Involvement: To expose students to real world practitioners and client expectations a real project is selected each year for this studio. The actual project design and construction team along with the client participate in the studio by conducting
workshops with the students as well as attending project reviews. This gives the students a unique opportunity to learn from and interact with practitioners as well as be exposed to a real client. One of the challenges of a multidisciplinary studio is faculty discipline resources. Using outside practitioners not only helps fill this resource need, but we have also found the interaction with the students to be a very positive experience for the practitioners (Figure 1).

- Design Benchmarking: Although the real site, program and functional requirements of the project are provided to the students, the actual design is not. As the students develop their own designs they are required to benchmark their work against the real project design in terms of function, cost, schedule, site logistics and energy consumption. In this manner we view the ICBIMS as a bridge from the academy to the real world of design and construction.

![Figure 1: Outside practitioners consult with students during the 2012 ICBIMS](image)

The ICBIMS was originally offered as an alternative studio in the landscape architecture and architectural engineering curricula. Architecture students in the early years were primarily MArch students as interested undergraduate architecture students had to take this studio as a studio overload. Currently the ICBIMS is fully integrated into the curricula of all three departments allowing undergraduate students to take the course as an alternative studio (Architecture / Landscape Architecture: 5th year, Architectural Engineering 4th year).

For the first offering of the studio in 2009, we consciously decided to give the students a prototype design (an elementary school) due to our concern that the architecture students might use most of the semester to develop their designs leaving little time for discipline integration. We found this approach to be somewhat frustrating to the architects in particular. We abandoned this prototype in subsequent years allowing students to fully develop their own designs. We have found this approach to be more successful. However it must be noted that pressure must be maintained to encourage the architects to quickly establish their designs to allow for the desired integration period.

Projects for the last three years have included a day care center (20,000 GSF), another elementary school (approximately 100,000 GSF) and a complex, phased addition to a university student recreation building (120,000 GSF). Tasks undertaken in the collaborative studio include: architectural, landscape architecture and engineering design, energy analysis, cost
estimating, scheduling, constructability, site logistics, coordination and clash detection. Course content also includes: an overview of BIM and integrated project delivery (IPD) and their application to the design and construction process (including an overview of application challenges and legal issues), current BIM software as well as BIM / IPD trends in the design professions and construction industry. The primary nature of this course however is a collaborative interdisciplinary design studio.

Student feedback on this studio has been uniformly positive. As with most design studios students find the course to be demanding. For all students it is the first time they have had to collaborate with so many disciplines. We encourage the use of an integrated design process from the start and the architects and landscape architects, in particular, find it challenging to integrate so much input at the beginning of the design process. The architectural engineers also find it rather intimidating to be looked upon as the “expert” in their discipline for the design of a complex building. In addition to gaining significant experience in developing and manipulating a complex BIM model, students taking this studio find they gain an appreciation and in-depth understanding of other disciplines, the interdependency of the disciplines in the design process as well as the “lead / lag” challenges in a multi-discipline effort.

As part of the research portion of the ICBIMS course, and prior to the start of the design, we have each team develop a BIM Execution Plan which outlines the team goals, organization, decision process, individual responsibilities, schedule, required digital tools and information exchange points. As their process evolves during the course of the semester, the teams are required to update the plan and provide a “lessons learned” analysis of their process at the end of the semester.

Four major presentations are made during the semester (one BIM Execution Plan and three design presentations). The presentations are made via a large, three-screen, rear-projected display (Figure 2). Participants in the actual project team as well as other outside jurors are invited to the presentations.

Figure 2: Students present their projects via a large, three-screen, rear-projected display
As noted, the feedback from practitioners who have participated in the ICBIMS course has been very positive.

“I think what you are doing is the way we should be teaching our students. It is important that architecture students and AE students learn their craft individually for a while so that they can master their own portion of the work. However, NO project is done by just an architect. All projects are the result of collaboration and interdisciplinary understanding. Any architect who emerges from school with an understanding of what the rest of the disciplines across the table are doing is far better off (and far more marketable) than those who emerge with purely theory and esoteric design wanderlust. Thanks again for letting me see a great learning process”.


“The concept of replicating multidisciplinary project teams engaged in a re-interpretation of a real project’s design and construction program is simply brilliant—as is the active tutor involvement of the actual project team. I particularly enjoyed watching the students “walk in the shoes” of their respective disciplines and struggle with competing agenda, goals and egos. This is great training for the real world.

They’re learning what we’ve discovered; the software and technology are indeed important but they become even more valuable as ‘carriers’ for collaboration and a powerful team adhesive.

Students demonstrated good foundational understanding of the software and were encouraged to push limits of practical application on their projects yet recognize the limitations of several packages which are still ‘works in progress’. This leads to another valuable lesson; the balance between practical innovation and wasting time on the pursuit of deep rabbit holes of non-interoperative tools which, in some cases, produce dubious results. These students are not just being trained in current best practices of the design and construction industry but they’re actually leading the industry—demonstrating what will become the new standard of care for high performing teams in the near future”.

John Tocci, CEO Tocci Building Companies, Chairman of ABC BIM Forum ICBIMS participant 2011

2. INTERDISCIPLINARY COLLABORATION FOR A CHANGING PROFESSION

Two recent surveys conducted by the National Council of Architectural Registration Boards (NCARB) and the National Architecture Accrediting Board (NAAB) conclude educational gaps exist in preparing students for professional practice and eventual licensure. The NCARB 2007 Practice Analysis of Architecture (NCARB, 2007) surveying licensed architects identifies 17 areas of knowledge and skills that students and interns are not receiving either in school or during their internship period prior to licensure. Many of these gaps occur in the business of architecture including construction management, project and practice management but also extend to computer technology training such as BIM and other design computing. Practitioners listed the second highest professional development need as computer technology including BIM
The recent NAAB *Study of Accredited Architectural Education* (McKinley, 2012) builds upon the NCARB study surveying a broader audience of educators, students and practitioners from varied practice settings. NAAB notes the purpose of the study is to “capture feedback on the changing field of architecture, the future of accredited architecture education, and the impact of past changes to the NAAB Conditions for Accreditation on architecture education.” When asked what is the “most significant development to impact the field of architecture” 15% of survey respondents cited BIM; this was the largest specifically cited item after sustainability factors. The changing nature of the profession and IPD also was cited frequently. When asked, “How might the change you described affect accredited architectural education?” the largest response category was “more technology training, fabrication (e.g. BIM, IPD), technical skills (19%).” More emphasis on collaboration/teamwork was the sixth highest category response (5%). Nearly all participants (96%) believe that architects exist in a working environment that requires collaborative teamwork with other types of professionals. The promotion and strong support of BIM and other interdisciplinary learning by architecture engineering accreditation through ABET is similar to NAAB.

The NCARB and NAAB survey results correspond to our experiences teaching the ICBIMS studio. While much of the attention is placed on the highly pragmatic value of learning BIM software for future employment, we have found the collaborative and interdisciplinary structure of the course helps meet the widest range of Student Performance Criteria mandated by NAAB (NAAB, 2009). All 12 criteria of *Realm B: Integrated Building Practices, Technical Skills, and Knowledge* are substantially met by the course (predesign, accessibility, sustainability, site design, life safety, comprehensive design, financial considerations, environmental systems, structural systems, building envelope systems, building service systems, and building materials and assemblies). Due to the broad design and engineering skills of the team, projects executed over the one semester course are more comprehensively designed than those executed by architecture or engineering students working alone over two semesters. The trade-off, for some, is that the architecture, landscape architecture and engineering student is not the sole author and expert for the entire project; however, in light of the NCARB and NAAB studies, we see the broadening of team expertise to acknowledge the reality of contemporary practice as highly advantageous. The model of “learning through collaboration” in the ICBIMS vs. “learning through individual execution” in the conventional studio is leading to more breadth in awareness of the related disciplines as well as more depth in the execution of a fully-designed comprehensive building. As a consequence, we believe the ICBIMS course serves as a model for architecture programs meeting the tough accreditation standard of Comprehensive Design.

We also contend that many of the NAAB *Realm C: Leadership and Practice* student performance criteria are substantially met in this studio. Conventionally, most Realm C criteria are included in standalone, lecture-based, professional practice courses. While NAAB has urged schools to meet the criteria through a broader array of courses, most schools have found expanding the subjects into already packed curricula very difficult. The ICBIMS integrates the criteria into the design process utilizing the expertise of each student and their corresponding discipline of study. Collaboration, leadership, legal responsibilities, project management and the client’s role in architecture are, to varying degrees, practiced as a natural part of the comprehensive design process.

Our 2014 architecture accreditation visit will allow for an outside assessment comparing the results of the ICBIMS with the normative non-collaborative, singular discipline design studios. An internal self-assessment survey of architecture students in the ICBIMS course was conducted
in spring 2012 (Weinreb, 2012). The students were compared to a control group taking the normative full-year thesis/comprehensive design course while the ICBIMS students take a one-semester thesis design course in the fall prior to their ICBIMS semester. The survey indicates ICBIMS students rate their overall comprehensive design skills higher across the eleven student performance criteria comprising this knowledge area. The survey also suggests the full-year thesis students focused more on “architecture first” and “integration later” vs. the more holistic and collaborative approach to integrated design in the ICBIMS. Interestingly, the shorter duration for the fall thesis studio course for the ICBIMS students resulted in more coherent and complete projects than their classmates. The small sample size and the self-assessment nature of the study makes it difficult to draw broader conclusions of the course effectiveness, especially related to student preparation for the profession and eventual licensure success. We hope to conduct a longer-term study tracking the professional paths of our graduates to determine if the ICBIMS course is consequential for their future careers. We do know that our graduates are able to quickly find employment despite the economic downturn, although somewhat surprisingly, some choose to start in smaller firms not yet equipped to make the most of their BIM-specific knowledge.

3. IPD AND BIM BEYOND THE BUILDING

In addition to the building, the ICBIMS also challenges students to design the site of the building. Students in landscape architecture are asked to develop accessible circulation systems, aesthetic landforms, and manage stormwater. They are also asked to specify detailed site materials and sustainable plantings that compliment the team’s overall design intent. To accomplish these tasks, BIM plays a smaller role for the landscape architecture students. This is in part due to the limitations of current BIM technologies. Although current versions are better, Revit does not include many tools for site design. Students spend a significant amount of time creating their plant materials and site furnishings libraries and working on their landforms in other programs such as Civil 3D. Landscape architecture students do utilize Esri ArcGIS Desktop to analyze site conditions to conclude zones of suitability on new buildings on flexible sites such as the 2011 Elementary School Project. However, this was not the case for the 2012 University Student Recreational Building addition as the existing building and roads already constrained the zones of development for the designs. With the limitation of the software true model integration is not always accomplished. Some teams maintain separate site model and building model and other teams only reference the site geometry into their building models. Although BIM plays a smaller role for integrating geometry for the landscape architecture students, they gain a great deal from the integrated approach to design.

Beyond BIM, the real gem for the students in the ICBIMS is developing well-informed designs through the IPD approach. In this approach students learn how to respond to and guide another discipline’s design. Landscape architecture students learn the importance of daylighting in a building; the heating and cooling loads required for a space with glass curtain walls; the accessibility needs of a mechanical space; and the costs of the structure for a cantilevered steel roof. Architecture and engineering students learn about balancing earthwork from shifting a building’s finished floor elevation; how the roof geometry and a material impact stormwater; the accessibility issues for their entrances; and the true costs for going green.

Students learn the lexicon of their allied fields. Whether they know how to calculate the variables is not important, the knowledge of what the controlling factors are and how their designs might optimize that variable is the gem of the IPD process (Figure 3).
4. THE FUTURE OF THE ICBIMS COURSE

As we enter the fifth iteration of this studio, we continue to make adjustments seeking greater student access, more fluid communication processes and deeper levels of informed interdisciplinary design decision-making. As accreditation boards promote wider exposure for students to acquire BIM software skills and participate in interdisciplinary collaborative learning, infrastructure and scheduling challenges resist accommodating increased enrollments. Over the past four years we have increased student enrollment 67%, from 18 students to 30 students, yet we are not able to keep up with student desire for participation. Enrollment limits are largely a product of access to properly configured team workspaces and the ability to schedule students, faculty and consultants. Common to most architecture school design studios spaces built over the past several generations, the studio workspaces at Penn State are mostly arranged for the needs of individual students working independently. We continue to seek to add and reconfigure more collaborative workspaces to enhance collective learning, design decision-making and team presentations. Additional access to BIM coursework through workshops and associated software training is now offered to all architecture, landscape architecture and engineering students. More engineering students now have access to an alternative collaborative BIM thesis capstone project option. Although limited to engineering student teams, this more limited model of ICBIMS serves as an expansion model for future architecture and landscape architecture students working together.

Penn State’s broad academic offerings in the building sciences (four architecture engineering disciplines plus architecture and landscape architecture) is enviable; Unfortunately, it doesn’t solve problems of fluid information sharing and flexible course scheduling between the participating six disciplines, three departments and two colleges. We continue to seek “workarounds” for University cyber-security demands that result in cumbersome and frustrating software and design data sharing between students and consulting professionals. The proximity of students in a university setting allows constant face-to-face information sharing/problem-solving often not available to professional teams. As the ICBIMS course evolves to include projects at more distant sites and with dispersed consultants, we will be facing some of the same telecommunication challenges interdisciplinary teams now face.

Choosing the right project for the studio each year is a tricky balancing act. We attempt to integrate the “real-world” challenges of program complexity, legal restrictions, phasing and renovation parameters, engineering options and landscape/site constraints while providing adequate “lead-lag” time for an integrated design approach. We have found the condensed 15-week project length to be very tight for multiple design iterations and incorporating revisions suggested by the team’s performance models. Interestingly, the condensed schedule also has a healthy affect: students leading the early design decisions are motivated by the team to quickly
resolve design direction, a condition often missing from conventional independent studio projects. Our goal in future project selection is to allow adequate time for performance modeling to inform more of the course’s sustainability goals.

As part of ICBIMS course and other IPD / BIM efforts at Penn State we hope to continue research into the development of BIM execution plans, creative teams, collaborative work / learning spaces as well as virtual studios. We intend to explore potential partnerships with the AEC industry in these areas of critical research.

When we started this course the academic obstacles emerged from either the lack of awareness of BIM or the apprehension/antipathy some academics have of “simply teaching software” that is best left for the profession. By coupling the software knowledge of BIM within the pedagogy of collaborative and interdisciplinary design, we have succeeded in satisfying much of the early doubt. Today, the question is no longer if it is worth doing, but how we do more of it…and better.

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REFERENCES


