AC 2009-1724: COLLABORATIVE TEACHING TO CREATE INTEGRATED BUILDING ENVELOPES

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Collaborative Teaching to Create Integrated Building Envelopes

As a former practitioner the rewards for offering courses that expose students to the principles and issues surrounding design in a context that emulates real world situations is invaluable. Two years ago an idea developed into a course which includes students from three different disciplines; architecture, architectural engineering, and construction management, as well as, faculty from these same disciplines to create an all encompassing course on building envelope design. The idea was to expose students to multiple facets of design and to expose students to the ramifications of their designs by considering construction and sequencing issues.

Introduction

The design and construction industry in the United States has started recognizing the value of collaborative efforts in producing buildings, thus the growing popularity of design build and integrated practice models. These delivery models emphasize the economic benefits of working collaboratively, but more importantly opening up the lines of communication during the work flow process - from design through construction and continuing through occupancy. In an academic setting, there are no economic forces driving disciplines or departments to unite in a more efficient and effective manner. But the rewards of teaching in a collaborative model can be professionally fulfilling and ultimately better prepare students for the future.

Recent papers, such as those in the American Institute of Architects "Report on Integrated Practice" (2006), suggest that a number of developments in the profession are overlapping, which "dissolve professional or disciplinary distinctions."[1]. Daniel Friedman's paper in this Report suggests three developments that will change the way that design is taught. These are:

1. A shift from static to dynamic form and the development of design pedagogies that use animation software; three dimensional scanners that can capture complex forms and the computer numeric control machinery that can replicate it.
2. The coming together of dynamic form with a broader application of sustainable technologies. The adaptation of technologies from other industries, such as aerospace or shipbuilding to create a new framework for collaborative practice as well as efficient design, manufacturing and assembly processes.
3. Using Building Information Modeling (BIM) to create a virtual model of the building that allows for the specification and performance testing of all the components of the building before it is built. BIM also increases the dynamic communication between the members project team allowing for fast and effective feedback from each discipline in the design development process.[1]

The idea of infusing a multi-disciplinary approach in the classroom is not new to academia, but using professors and students from multiple disciplines is unique. The key to the course was finding viable projects, identifying the appropriate learning outcomes, and most importantly finding professors who shared the same vision and approach to design - much like team building in the real world.

The model for this class is inspired by what is happening in industry today, where there is the need for improved collaborative design, faster product delivery, and more efficient buildings combined with more effective, transparent communication across the entire project team. Currently, research into integrated practice is being supported by professional institutes, including the American Institute of Architects and other architectural, engineering, and construction related organizations. It is imperative that the curriculum in professional programs reflect current practices by introducing students to multidisciplinary models and emerging technologies.

The Class Philosophy

The idea of offering a building envelopes course started as an idea to expose students to design and construction issues dealing with the facade; massing, materials, attachment, day lighting, thermal comfort, sequencing, and fabrication. In addition to these topics, the course has become an experimental course in building information modeling (BIM) where students can explore there designs in 3D from inception to fabrication. In order to achieve a high level of coordination and collaboration, the course required the skill sets from more than one instructor and instructors with varied backgrounds.

Fortunately, the college has professors who have changed careers and have developed a passion for teaching and who bring their professional design skills into the classroom. In the building envelopes class, the two professors have varying exposure to buildings, but the process in which they delivered projects was very similar. Additionally, both see the value in communication amongst disciplines and the need for integrated practice in a classroom setting. The class has become a vehicle to prepare students for the real world by exposing them to the priorities of each discipline, as well as, showing the students how design projects, when driven by collaborative motives, can be inspirational and cost effective.

The class is structured around the concept that the instructors are also an integrated project team. As noted previously, the instructors are from three disciplines; architecture, structural engineering and construction management. Combine this with a mix of students from these disciplines and it is possible to encourage students to collaborate on a series of projects during the term. The students work as an integrated project team the entire quarter.

During discussions about building envelopes, students gain an awareness of how the building profession is evolving. To better prepare them for the design profession, today as well as the future, practitioners are brought into the classroom to share real world experiences and to critique student work on design, fabrication, and construction. In rare situations, studios have the luxury of having three or more disciplines reviewing student work and in this forward thinking course, reviewers with expertise in architectural design, facades, construction management, structures, and environmental systems review student work. It's the holistic feedback students receive that will better prepare them for the future and expose them to the power of an integrated design approach.


Figure 1: The IceBreaker Project – as-built condition on left, design proposals on right

Module One: The Icebreaker

One of the biggest challenges facing courses with multiple majors is creating a collaborative atmosphere. The first exercise, the Icebreaker, serves three purposes:

- begin working in inter-disciplinary teams in order to break down barriers and open lines of communication
- begin working with building facades or envelopes
- begin working with digital media which will serve as the vehicle for communication across disciplines

The assignment is to design, engineer, schedule, and estimate a proposed storefront design for a corridor that links the old to the new portions of the college. The student proposals ideally consider how facades can direct and guide users through a space; signify an entrance, while students also determine the best usage of materials for aesthetics, stability, cost and procurement.

The students are allowed one and one half weeks to complete the assignment, but during class students receive lectures dealing with connection and framing strategies, scheduling examples, and studies of basic storefronts that are deemed successful and less than successful. The projects, a sample project is shown in Figure 1, culminate with a multi-disciplinary presentation. All members are expected to speak about their project and the teams must discuss not only the genesis of their design, but the evolution of their design and how they arrived at their final solution.

At the end of the term, students provide a "reflective essay" that provides a means for students to provide feedback regarding this assignment. Students typically comment about the varying languages that separate the three disciplines, different motivations that sometimes clashed, and an initial awkwardness in working together. Every student in the class recognized the value of working collaboratively, but few understood the intricacies of working across disciplinary lines at this stage of the class. And this was the intent of the assignment, to blur the lines between disciplines and to begin the process of an integrated design approach.

Module Two: The Precedent Study

The next module deals with expanding the student's knowledge and exposure to progressive building envelopes. Students are required to research a recently completed building which exemplifies current building trends and which implemented a collaborative design team

approach during design and construction. The project goal was to expand the student's vision in regards to what innovative concepts have been used today and where one might push technology when designing the envelope of tomorrow.

In preparation for the precedent study, students are exposed to the building envelope, from prefabricated stick systems to modular panelized systems and from green roofs to double skin facades. For a typical topic, such as materiality, instructors from each discipline speak about how materiality impacts that portion of work. The architecture instructor describes issues related to color, massing, texture, etc. while the structures professor examines the issues surrounding mass in terms of engineering, deflection, and jointing. The construction majors learn about procurement, installation procedures, water proofing issues, and testing related to material selection. After the topic is discussed from all perspectives a round table type discussion ensues where student questions may be answered by all the instructors present. By using this system, the students get three perspectives from the professors rather than one point of view. This process allows the instructors to impart the necessary knowledge so the students can explore other building skin systems in detail. In terms of learning, the students are provided with the tools necessary to analyze sophisticated systems and to evaluate the pros and cons associated with the precedent project. [2]

As part of fulfilling the project requirements, students conduct a site visit and interview a building professional associated with their precedent study building. The students may speak with one or more of the following; project architects, structural engineers, environmental engineers, building façade specialists, construction managers, or facilities managers. The goal is for the student teams to learn the historical tracings of the design and construction and to see the project first hand. Something that a purely literature search can not provide. Students typically present an interesting anecdote or war story about the project that adds additional interest to their submittals.

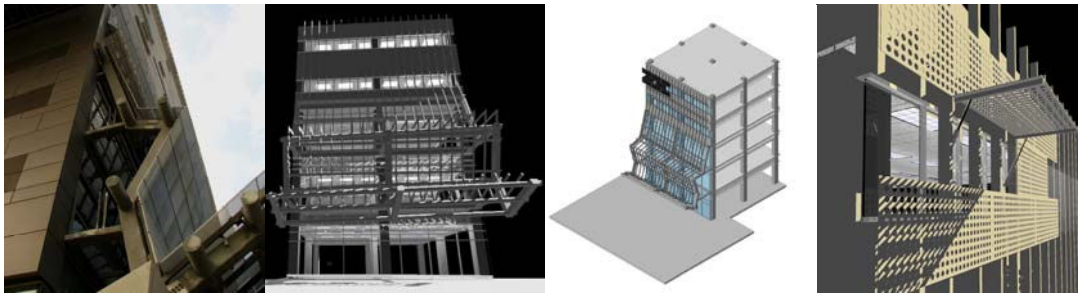

Figure 2: The Precedent Study – as-built image on left and 3D images on right

The Precedent Study submittal is similar to the Icebreaker submittal. The student teams are required to explain the rationale and inspiration for the design, the inter-relationships between architecture, structure, and construction, and issues related to cost and special installation procedures. The students use 3D modeling and construction photos to document their findings (see Figure 2 above). Students are evaluated on their graphic communication, analysis of architectural and structural design, determination of the construction methods, etc… The more important evaluation is the teams understanding of the inter-disciplinary relationships present for the precedent project and their ability to communicate/articulate this orally. A sample grading sheet is provided on Figure 4 on the last page of this paper.

But, the most valuable part of the presentations is the sharing that ensues as part of the oral presentations. The class is exposed to a variety of projects and is provided with detailed information about innovative and sophisticated building envelopes. With this information the teams are ready to begin the final phase of the class which is to design a building façade of their own.

Module Three: Designing a Sophisticated Building Envelope

In the final module of the class the students are required to synthesize the information to date and then begin the design process for the corner of an imaginary three story building. The student teams design the roof and two sides – south and west facing – such that varying design strategies need to be implemented and evaluated. The teams are required to demonstrate innovative uses of the building envelope that not only trigger a positive visual response, but also address internal design issues related to thermal comfort and day lighting.

The Building Envelope Project evolves over a three week period. Students were given two weeks of lecture material interspersed with guest practitioner presentations on more in-depth topics such as building delivery methods and procurement, structural analysis and building code implications, and installation and water proofing protocols. The lectures and presentations were spread over a three week period and work sessions were scheduled on "off" days. The mixture in modes of instruction allowed the instructors to provide "desk crits" to the individual teams rather than generic lessons applicable to all.

Figure 3: The Building Envelope Project – proposed façade, connection detail, and cost table

The projects were required to implement BIM. In most instances two models were created and shared between disciplines. In some instances, teams used different software and converted the software to a common platform for coordination and design. These projects typically demonstrated a deep understanding of the façade design, the construction process, and demonstrated a high level of coordination across disciplines. A sample project is shown in Figure 3 above. Students typically provided separate but related solutions for the west and southern facing walls and documented the structural system such that connections were detailed to account for lateral drift, vertical deflection, and construction sequencing. The construction estimates were based on prior knowledge or from contacts established through the precedent study project.

For the final review, a guest jury was formed with teaching faculty, two or three guest faculty from all three disciplines, and one or two guest practitioners. All the reviewers were asked to fill

out an assessment form to provide feed back for the students and the faculty when a final grade was assigned. As a side note, the practitioners and guest faculty had a tendency of awarding the lowest marks on the student's oral presentation skills. While this is a topic for another paper, in response to this, the oral presentation portion of the submittal was assessed with more rigor.

Lessons Learned and Student Feedback

As part of the course final, a reflective essay was assigned. Students were asked to describe various aspects of the class, but more importantly they were asked "what worked and what didn't work." Some students learned the BIM software for the first time during the class and this turned out to be an issue when completing the projects. In the first year, students were required to use the software for the first and third modules only. Since the students were only learning the program, they recommended that the software be required for each project to help them become proficient with the software and enable the team to coordinate digitally. In response, we have required that each project be documented with BIM software.

Almost all students comment on the importance of an integrated approach and that their initial thoughts about integrated practice evolved as a result of the class. Most observed the importance for all team members to "be on the same page", stating it was a necessity to achieve the goals of the team. Discussions about design and construction ceased and were replaced by thoughts about integrated delivery models and how one might use these processes in the future.

Another key suggestion/observation is the involvement and representation from all disciplines - both from academia and from professional practice. For the past two years we have been fortunate to have enthusiastic support from alumni in the construction and engineering industry. Our industry friends have given this course credibility that we can not impress upon the students as faculty members from an academic institution.

The one topic the authors will continue to stress will be the importance of starting the design and collaboration process early. Since the students come from three different majors they all have classes at different times of the day making it hard for them to find spare time during the day. Due to the lack of common free time, some projects suffer from a compressed collaborative effort. While these projects show promise and a level of sophistication, the products from these teams lacks the fine tuning possible when working in a collaborative environment from start to finish.

Conclusion

The first two years of the Integrated Building Envelope class demonstrates methods for teaching a multidisciplinary elective course at Cal Poly – San Luis Obispo. Choosing external building envelopes as the subject for this class allows students to focus their attention on one aspect of building design – a decision influenced by a 10 week teaching term. By focusing on the building envelope versus the entire building, students were able to explore design, engineering, and constructability in greater detail. Lectures were given by instructors and invited guests from industry, including construction managers and cladding manufacturers, thus exposing the students to a variety of approaches related to the subject.

One of the greatest challenges facing architecture, engineering and construction (AEC) educators today is effectively integrating interdisciplinary aspects into their curriculum. The AEC professions have the opportunity to engage with each other to create more efficient frameworks for delivering buildings. These frameworks include working collaboratively in integrated design teams, effective communication models which enables immediate decision making, and the creation of highly efficient fabrication, delivery and construction systems [3].

Although the paper is based on an academic setting, the principles behind group dynamics, communication, and integrated design are universal to the building profession at all levels – education through seasoned practitioner. Participants in the building envelopes course leave with a knowledge about design and construction processes that may be implemented in practice when they enter the work force. The influence of pilot classes like this one are potentially far-reaching and create an opportunity for revising professional curricula to hybrid models of instruction and partnerships with industry to stay current with the needs of the real world.

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ARCH X410 + ARCE X410 + CM X410 Fall 2008

I N T E G R A T E D B U I L D I N G E N V E L O P E S

PROJECT THREE: DESIGN OF AN INTEGRATED BUILDING ENVELOPE

Presentation

Student name: ..... **initials**: .....
Student name: .....
Student name: .....
Student name: ..... **date**: .....

Criteria	1	2	3	4	5
1. Design Development of envelope system – What type of system is being used? Does it have a typology? Why was the system used? What materials and textures are used to enhance the design? How are day lighting and thermal comport issues addressed?					
2. Design Development of materials – Is the there an understanding of the materiality and structure of the project? Do materials affect the way the building is designed and detailed?					
3. Design Development of structure– How does the structural system respond to the forces and how is stability maintained? How is the skin attached to the structure? Is the primary structure integral to the building envelope or is the envelope a separate system? How does the envelope work with the building displacement due to wind and seismic?					
4. Construction issues – How did the proposal change during the design process by incorporating constructability issues? Why is this system the "best fit" for this system? Are there alternatives that maybe more economical? What parts are pre-fabricated and which parts are field assembled? What type of weathering issues impacted the design? How are issues such as procurement, scheduling, and installation addressed?					
5. Integration of the Project Team – How does your proposal respond to the "need" of each discipline? What is the relationship of one discipline to the other for the proposed scheme? Was BIM used effectively to increase integration					
6. Presentation – communication - The effective communication of information and use of visual media to demonstrate knowledge and the design strategy on one panel, beautifully composed. Was BIM used as a communication tool?					
7. Hand-in copy of documents – pdf	yes			no	
8. Comments.					

Key to grades
5. = A; **4.** =B; **3.** =C; **2.** =D; **1.** =F.

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Figure 4: Sample Grading Sheet – used by faculty and guest reviewers