

Teaching Integrated Practice in a Cross-Disciplinary Curriculum After Two Years

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The single most devastating consequence of modernism has been the embrace of a process that segregates designers from makers. The architect has been separated from the contractor, and the materials scientist has been isolated from the product engineer.

The automotive, shipbuilding and aircraft industries, however, have developed models of engagement that integrate all acts of design and production. Their design departments and production departments have ceased to exist as independent entities within large organizations. Designers and producers are members of a team that comes together to solve specific problems.

Stephen Kieran and James Timberlake, "Refabricating Architecture: How manufacturing technologies are poised to transform building construction," 2004¹

INTRODUCTION

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 integrated collaborative design teams, effective and immediate communication and decision making, and highly efficient fabrication, delivery and construction systems.

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."² Daniel Friedman's paper in this Report suggests the three developments that will change the way that we teach. 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 form 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 adaption of technologies from other industries, such as aerospace or shipbuilding create a new framework for collaborative practice as well as efficient design, manufacturing and assembly processes.
3. Using Building Information Modelling (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.³

This presentation addresses how two faculty members at Cal Poly are addressing these interdisciplinary shortcomings in traditional AEC curricula and

suggest ways to create a seed of greater strategy in linking curricula to practice and increasing communication between departments across our College. Central to our efforts is a shared interest in the holistic approach to developing a design solution. We believe the process of making buildings is interactive among disciplines with each discipline constructively contributing to the design and efficiency of the process.

How can we teach this kind of current industry best practice integrated framework in a single disciplinary curriculum? The case study method provides the best opportunity to do so. By studying on a case by case basis the various frameworks of integrated project teams, there can be an effective introduction of these concepts to students. In each discipline it is possible to introduce and explore these projects in this manner, but it is not the fully integrated learning experience that we all strive for. This approach of single discipline teaching is limited, as are the traditional constructs of the design-bid-build method, without project team integration. The sequential nature of this design-bid-build project framework creates a disconnection from the disciplines who are gathered for the same goal, to create a building. We feel this outdated design and building structure is no longer the only perspective that students should experience. There are new concerns that are part of the considerations for the design of a building. Considerations that are more complex than the experience of people in one profession. It is becoming necessary with legislative requirements for energy, sustainability, and the increasing material and labor costs require new interdisciplinary approaches to a project much earlier in the process. The preferred situation for a fully integrated project team changes the contractual basis for a project to design-build. In this scenario, the project is created by an integrated interdisciplinary team which is working toward the same goal. The structure we implemented for teaching this class is a team of interdisciplinary instructors who understand the unique perspectives of each profession.

Our class is structured around the concept that the instructors are also an integrated project team. This includes instructors from three disciplines; architecture, structural engineering and construction management. We combine this with a mix of students from these disciplines collaborating on a series of projects during the term. The students

work as an integrated project team.

Our initiation of this class was based on a framework of opportunities.

- Interdisciplinary aspect of our college allowed easy access to three departments: architecture, architectural engineering, construction management
- Having professors with extensive industry experience
- Students with a strong “learn by doing” approach to learning
- Strong connections to a regional alumni network in each discipline
- Guest lectures by people from industry
- Dean who supports interdisciplinary teaching
- Proximity to two large metropolitan areas with some excellent examples of cutting edge external envelopes

The desired structure of the learning environment involved a couple of different factors:

1. A mix of students from the three disciplines on each team
2. An effective sequence of projects to enhance the learning experience

Because of the short 10-week term structure we have at Cal Poly, it was decided that we could effectively look at only a part of a building. We both had professional experience and research interest in external cladding systems. This seemed to be the logical focus. External cladding is a complex system that each of the disciplines usually has a say in. The architect can design it and is invested in its aesthetics, the structural engineer needs to understand the design, propose effective structural supports and analyze material performance, and the construction manager wants to make it cost effective and buildable. Building envelope systems are perhaps the most scrutinized element of a building by the design team.

THE CLASS VERSION 1.0: ANALOG

The goal of the class was to give the students the experience of working on an interdisciplinary proj-

ect team. The learning objectives can be summarized as follows:

1. Work collaboratively in a multi-discipline team;
2. Synthesize architectural issues in building envelope selection design and construction;
3. Manage construction issues related to material procurement, sequencing and erection;
4. Examine structural design issues related to building envelope systems, material selection and design;
5. Demonstrate a fundamental understanding of human comfort issues;
6. Choose the appropriate process of design and assembly for building envelope systems that integrate architecture, structure and construction;
7. Understand the interrelationship between design, time, constructability and cost.

We saw the class as being a hybrid teaching environment using both lectures and project based learning to explore the numerous topics related to the building skin. Three main components were developed to achieve the learning objectives:

1. Lectures and roundtables
2. The envelope analysis project
3. The envelope design project

During the first half of the term, a series of individual lectures and group round table discussions were presented by the instructors. Each instructor presented detailed material about his individual discipline's relationship to building envelopes, which created a dynamic learning environment when we participated in group round table discussions; fielding questions from the other instructors and the students. Supporting these instructors' lectures were a series of guest speakers from industry including project managers, engineers and external cladding

manufacturers, who gave the students other viewpoints. While this material was being presented the students were asked to work on a research-based project, the envelope analysis. This analysis project required the student teams to work together to create an in-depth case study examination of a single building envelope. The buildings were chosen from a short list of buildings that were accessible, having a certain degree of complexity and a high level of aesthetic consideration. [see fig. 1] The envelope system was to be dissected by each of the disciplines. The focus of the assignment was a series of three-dimensional analytical drawings that included axonometrics and cut away perspectives analyzing the envelope system and how the envelope was constructed. The drawings conveyed the elemental nature of the envelope. It was mandatory that the students visit the buildings and be able to contact one member of the design/construction team who had access to drawings, documents, and first-hand knowledge of the process of creating the envelope system. The analysis process minimized speculation, seeking information from primary sources and presenting the facts in a critical manner. Real buildings are riddled with compromises and these can only be understood by talking to people involved in the project. Particular details of these aspects were required to be part of the student team presentations. Generally, the process of design and construction was asked to be reconstructed by the students, enabling team members to understand the roles of their counterparts. The architects explained the design concepts and design development of the envelope, the structural engineers learned to describe the underlying engineering principles in layman's terms and their concern about structural performance and coordination, and the construction managers discussing cost, fabrication, delivery and assembly of the envelope. Each individual discipline was asked to explain the level of integration of their discipline into the project team and how the project team was structured.

The second half of the term is devoted to the envelope design project. The student integrated design team designs, engineers and provides costing for the construction of a building envelope. Information is given to student teams for the development of a new building envelope with a scope limited by the following parameters; it is a commercial office building, document the corner condition with one face facing south, three story minimum building

Advantages of Scrim Wall

- Reduce heat gain
- Acts as a convection cavity
- Reduces long-term operating costs
- Buffer between the building and skin



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Integrated Building Envelopes - 11/2/2006
Case Study

The Truss on the West End

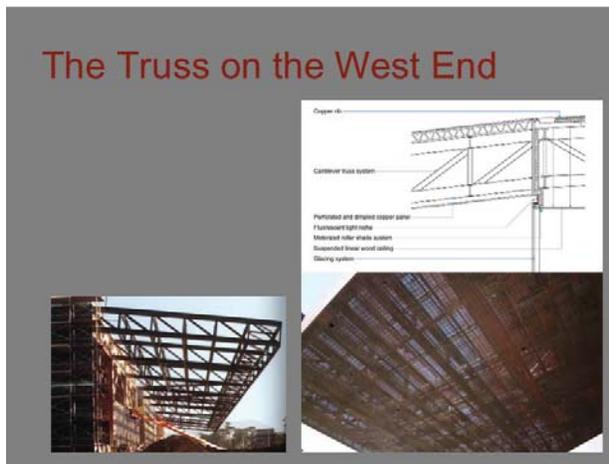


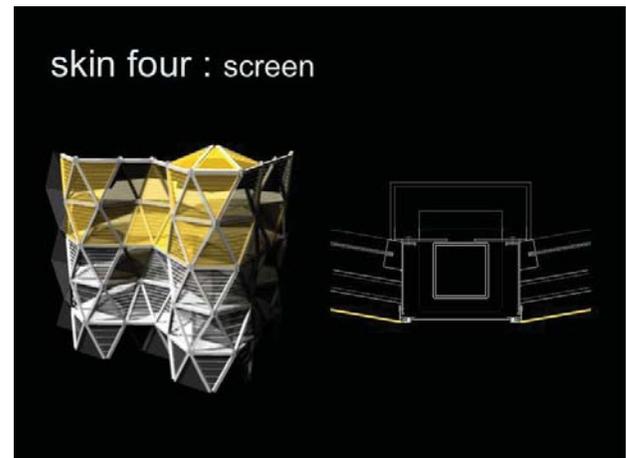
Figure 1. Envelope Analysis projects: Caltrans by Morphosis, De Young Museum by Herzog de Meuron.

height, and a multi-story space is behind one face of the building. The teams are asked to prepare a design, engineer and provide construction management skills for installing the envelope system, and provide documentation of the process. The teams developed the project using both class time for desk crits and out of class time for team coordination, research, and development. The team members participated as equals in deciding the criteria for the specifics of the envelope. Each discipline contributed their knowledge or provided research to support their ideas for the envelope design from the beginning of the project.

The student teams drew upon their experience from completing the case study, the lectures and invited guests. The process includes a structure similar to a design studio, with class time opportunities for desk crits by the instructors and project reviews. The final reviews required the student teams to

present their designs in three-dimensional graphic form, a calculated structural analysis with appropriate detailing, costing breakdown, and a buildability analysis that describes procurement, scheduling and installation.

As part of a final evaluation of the students' absorption of the material we included a final exam with essay questions. The questions varied from topics germane to the issue of integrated project teams and building envelopes to a self-reflective question for the individual student about their experiences in the class. This critical post-project reflection by the students gave the instructors direct feedback about their learning experience and an often candid assessment of their interactions as members of the integrated student teams.



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Integrated Building Envelopes - 11/2/2006
Final project

Figure 2. Envelope Design Team Projects from Analog

OUTCOMES OF VERSION 1.0

The strategy of developing a team-taught interdisciplinary class has been a successful one. Our goal of providing a hybrid learning framework to introduce integrated practice issues using an integrated instructor team has created an effective and dynamic learning environment. The nature of integrated practice is exemplified by the dynamic nature of interactions within the team. While the lecture topics were carefully coordinated through the term to be able to cover appropriate material, the round-table discussions with full instructor team attendance became an exercise in “thinking on your feet” in a similar way to real world situations. Questions framed by other instructors and the students were unpredictable, partially because of the interdisciplinary aspect.

Everyone brought their own professional inclinations and viewpoints to the table. This professional dynamic of the round table sessions was also experienced by certain guest speakers and their presentations, as the instructors acted as the team leaders. These biases also became evident in the desk crit sessions for the envelope design project. It was interesting to the instructors, that so much of what a student brings to professional practice is instilled by the educational experience, without having the real world experience of working on a project team. The questions raised by the instructors at these desk crit sessions also created a dynamic that closely mirrored the real world, with certain tensions between the disciplines coming into play. We used these moments as a learning opportunity to explore the reasons why the tension exists.

The student feedback on the class has been very positive. Because of the close collaboration on the student teams, the students developed respect for their peers and the other professions. The comments we received from the reflective question on the exam generally had suggestions to the instructors about slight modifications in the content of some of the lecture topics (i.e. more information about fastening systems) and were very positive about the guest speakers who came. We also were given a little more first-hand information about the students experiences on the project team with both positive and negative comments about the predisposition of certain professions, which were informative and entertaining.

THE CLASS VERSION 2.0: DIGITAL

The second time this class was offered, one year later, we introduced building information modelling as a learning tool. The desire was to use this emerging technology of BIM as a method for creating a shared digital model that all the disciplines could use through the design process. The incremental nature of design requires open and current communication among the team members for the project to advance. We felt that a building information model was an appropriate tool.

In contemporary integrated practice it is necessary to develop new models and methods for communication. Even in a classroom or studio situation, where the project team is collocated, involved in the project from its inception and has a common goal of achieving a good grade, it is still necessary to support project communication between disciplines. We desired to look beyond traditional methods of construction documentation. The knowledge conveyed in a building information model was helpful across disciplines for a number of reasons. The information allowed for quick understanding in a language that was inherent in each discipline. The model typically contained the following information:

1. Graphical project data including digital models, allow for information to be viewed at various scales
2. Component data made up of intelligent objects
3. Non-graphic data including: specifications, cost data and schedules⁴

All this information is interconnected. As the team member viewed the design, it was possible to also see the schedule and quick costing data. This allowed the project teams to get quick feedback from the shared model.

This comprehensive and dynamic model requires intensive collaboration and coordination, which was time consuming for our students.⁵

This level of collaboration is a challenge in a classroom setting. In order to bring the students up to speed on BIM software we brought software

trainers into the classroom during the first week of classes and provided two days of training. This provided a good start up the slope of the steep learning curve. We also had the support of a dedicated teaching assistant who had already gone through a training session previously. The use of the BIM software was required on an initial short project for a shopfront on campus. This “icebreaker project” introduced the team members and began the collaborative process of effectively using BIM. As this project developed we all discovered the positive and negative aspects of BIM. The most positive aspect was quick visualization and communication of three-dimensional ideas to the team. The negative aspects included the need to customize smart objects, the building components that create the non-graphic data and the complex nature of creating details in the BIM software.

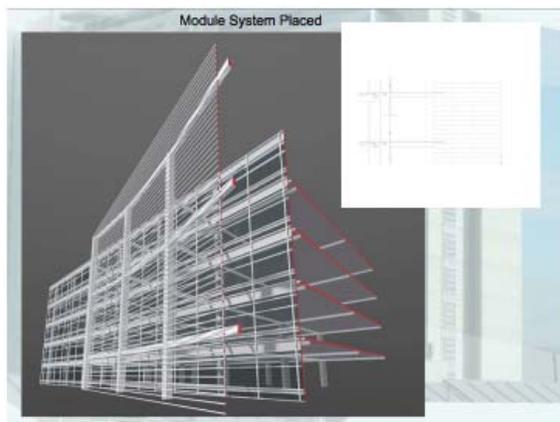
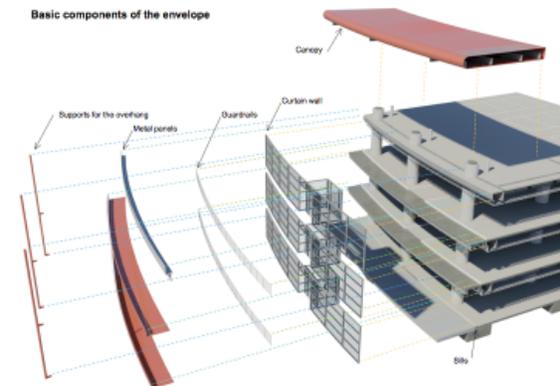


Figure 3. Envelope Analysis Projects: Clark Center by Foster and San Jose Civic Center by Meier.

As the quarter progressed with the same structure and projects as in Version 1.0, we decided to only require the use of BIM software for the final design project. This might have been a fatal flaw, as the students did not use the software for three weeks. When the final design project began, there was a slow start to the projects. This could be attributed to a number of factors, including team dynamics, but the slow start of the final projects seemed to be affected by the use of the BIM software. A few teams soon jumped to other three dimensional software that was suitable for complex modelling. The ability to work in another, more familiar, software then import the model into the BIM software allowed the student to produce information in the early stages of design more effectively.

We then saw the potential of using BIM as a communication tool. On the teams that spent time building

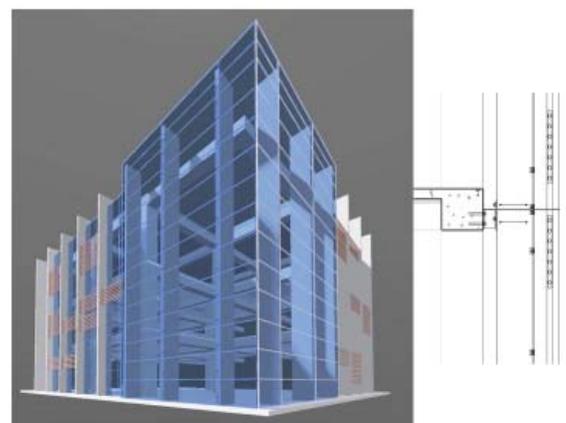
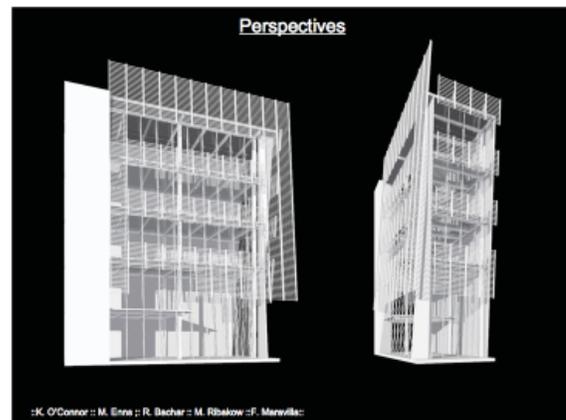


Figure 4. Envelope Design Team Projects from Digital

the information in the digital model we saw a very quick use of the information by each of the disciplines on the teams to develop their components of the project. The structural engineers identified the structural components and systems, and the construction managers were able to create spreadsheets and develop costing for the system. It was a struggle to learn the software well enough to get to this point, but the outcome appears to be fruitful. The teams that took the time to produce a useful digital model benefited with the ability to instantly access the graphic and non-graphic data. Of the four project teams, three created useful BIM files.

OUTCOMES OF VERSION 2.0

The student feedback to this class regarding the overall structure and the attainment of the learning objectives was similar to the previous years' class. The experience of multi-disciplinary collaboration, having guest speakers from industry, and the development of a team project were all given very positive feedback. We increased the information we presented on envelope detailing and fastening systems, and expected more detail from the students in their presentations on this topic. Ironically, detailing became an issue using the BIM interface.

The general student feedback on using BIM software was positive, and most students said that it was worthwhile to introduce and use this software in this class. Many understood and appreciated the connection between the software and the ability to use the digital model as a communication tool. Student comments and suggestions are collated into topics below:

Training and Time Issues

- Provide separate training process for each profession
- Needed more training, too much information was provided in a short time
- First project should be very specific to facilitate learning the BIM program
- Provide a series of short projects to reinforce the BIM program
- One proficient architect did all the modeling and this proved most efficient for the team.
- BIM training was a distraction and it was more important to do the project

- BIM training enhanced our learning ability in this class

Design

- BIM software limited creativity – couldn't get the software to delineate the idea effectively
- Using BIM software for renderings was problematic
- Custom or complex forms are too difficult with limited training and experience. It is easier to import complex form from other three-dimensional software.
- Creating a formal model and transferring it to BIM software made it easy to go from massing to plans, sections and structure

Documentation and Extraction of Information

- Special training was needed in the schedule and costing aspects of the software
- Detailing was not a benefit of the software – had to export and draw in CAD
- Most valuable use was to be able to show the construction process
- Creating custom objects and non-graphic parameters were difficult and time consuming
- No "fudging" was possible – problems cannot be hidden
- Can get accurate take-offs in very little time
- Converting model file in rendering programs was easy

Communication

- Three-dimensional model made it easy for the team to understand the design quickly
- BIM brought issues to attention of the team faster
- Really helped to communicate as a team
- Models could be passed off and used by other members of the team
- Good tool to model and solve issues in a spatial manner
- Architecture students know more about the software and the team relied on their capability

Evaluating this feedback made us aware of a number of new issues that will enable us to positively modify some of the framework for the class. This process also gave us some clarity about the class. This class is not a software training class. Our goals are to

teach integrated practice and building envelopes. We are using BIM as a communication tool. Given the difficulties encountered by our students when it came to detailing, we also needed to ask ourselves if BIM software was appropriate for exploring building envelope systems, or is a building envelope too detail oriented for the capabilities and training requirements of the software. The last interesting point that we observed was an awareness by the students about which professional practices (future employers) used which BIM software package.

CONCLUSION

The emerging technologies of BIM platforms allowed this class to be a pilot class for our school to begin using this software. Careful attention must be paid to how the BIM tools are used in an academic setting. There are a few well-published practices that effectively use these tools and suggest that BIM can revolutionize the profession, but this technological leap should be done while considering a parallel leap in design thinking. As academics we are responsible to create the foundations for the students life-long learning process, which involves a different sensibility than engaging the newest technical marvel. It is true that aspects of integrated practice can be addressed at a much higher level using BIM, and some of the potential liabilities of using this software in an architecture-only curriculum are circumvented by being used in an interdisciplinary elective class. We must also recognize that BIM is a representation and communication tool that requires answers to be entered, while design thinking is question-driven. Balancing these issues should be a goal of an integrated practice oriented curriculum.⁶ A concern that we have about BIM is the steep learning curve using BIM software and the short time frame of the class. The students require extra support, just for the software. If a strategy is in place, we can increase the level and speed of communication between the disciplines by using this tool, once the student become familiar with its capabilities.

This class has also been instrumental in developing new lines of communication between departments and instructors. In the academic environment it is too easy to stay cloistered from events outside your realm. The very nature of this teaching methodology breaks one out of this. The goodwill and friendships that have developed has already sparked a

number of other interdisciplinary initiatives for developing shared digital facilities and applying for grants. It is important to have cohesiveness and purpose when developing these interdisciplinary strategies, and this class has provided a focus for an integrated practice initiative across the college.

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ENDNOTES

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